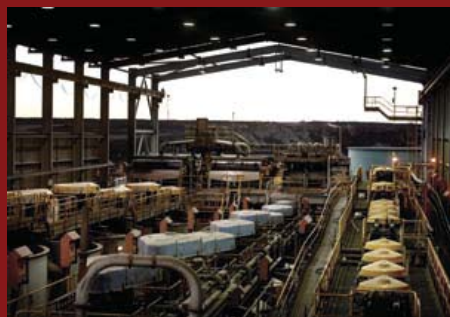
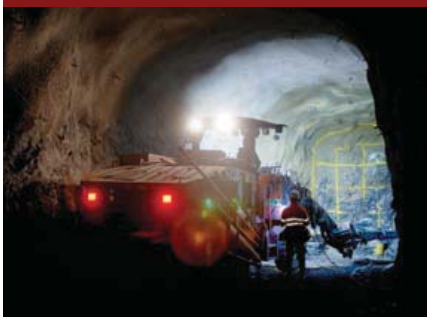


Mine Managers' Handbook

Monograph 26



MINE MANAGERS' HANDBOOK

Monograph 26

The Australasian Institute of Mining and Metallurgy
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CHAPTER 1

OVERVIEW OF MINE MANAGEMENT

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Established in 1988, Jellinbah Group is a privately-owned independent Queensland-based coal company with operations in Central Queensland's Bowen Basin.

The group has two operating mines, Jellinbah Mine and Lake Vermont Mine, with a combined production capacity of 13.0 Mt/a. The mines produce hard coking coal, low volatile PCI coal and semi-soft coking coal.

Jellinbah Mine is located on the Tropic of Capricorn, near Bluff, Queensland, and the product coal is hauled by rail to the Port of Gladstone, approximately 300 km from the mine.

The mine has been in operation since 1989. It is an open cut operation with overburden drilling and blasting, followed by conventional removal with truck and shovel and dozer push.

Jellinbah Coal is a low volatile bituminous coal with high specific energy, low ash and sulfur. With these properties, it is ideally suited to pulverised coal injection (PCI), blending for coke making and special coal boilers.

The mine has a current production capacity of 5.0 Mt/a.

Jellinbah Group has a 70 per cent interest in the Jellinbah operation and Marubeni Coal and Sojitz Coal each hold 15 per cent interests.

Lake Vermont Mine is located near Dysart, Queensland, and product coal is hauled by rail to the Port of Gladstone, Dalrymple Bay Coal Terminal and Abbot Point Coal Terminal.

Lake Vermont's first shipment was in February 2009. The mine is an open cut operation, with overburden drilling and blasting followed by conventional removal with truck and shovel and dozer push.

Lake Vermont produces high-quality hard coking coal and mid-volatile PCI coal.

The mine has a current production capacity of 8 Mt/a.

Jellinbah Group has a 70 per cent interest in the mine, with Marubeni Coal, Sojitz Coal and AMCI each holding ten per cent interests.

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1.1 BUSINESS STRATEGY

1.1.1 Strategy in context

A good business strategy will be well understood by all and should align behaviour around the goals and objectives of the organisation. It will be focused and succinct such that the essence can be readily recounted by all employees.

Collis and Rukstad (2008) stated that in order for a statement of strategy ('the what' we will be doing) to be effective it should contain three elements: an objective, scope (or domain) and an advantage. While an objective and scope can be fairly straightforward to define, coming up with an advantage (that sets one aside from competitors and attracts investment) can prove more difficult. For example, being a gold mining company with aspiration to grow annual gold production to a set target within a specified time takes care of the objective and scope but says nothing of the way this will be done to gain competitive advantage. Doing all this and aspiring to be the lowest cost producer may not be that differentiating and could even be somewhat difficult to believe, depending on how the growth is to be achieved. Similarly, having a value proposition that explains why a customer should buy the organisation's product above all the alternatives may be largely irrelevant (eg for gold) or stating the obvious (eg high-grade hematite lump with low deleterious elements). For many miners the competitive advantage will not be through appealing to the customer but aimed directly at the investment community. For example: achieving 'x' growth in 'y' years by developing internal assets only that produce upper quartile return on investment, or only choosing to develop assets held in specific areas of the globe. In today's world, much more emphasis is placed on how one undertakes mining and the legacy it leaves and this may play into how an organisation seeks to gain competitive advantage. This can have significant flow-on effects for not only aligning internal human resources with the way in which the goal is to be achieved but also appealing to the additional external human resources required to be recruited to achieve the goal.

Clarity between what is contained within a statement of strategy and what may comprise the organisation's mission, vision and its charter of values is important. The mission ('the why' we are doing it), the vision ('the what' we want to be) and charter of values ('the how we will conduct ourselves') usually sit above the statement on strategy (Figure 1.1.1) and are likely to be more enduring. An organisation that strives to conduct its business ethically is likely to adhere to the values that underpin this conduct for as long as the organisation remains in business.

The elements of the strategy, such as imperatives and priorities, for delivering on the goals and objectives of the organisation, whether contained within the vision or simply an underlying strategic goal, may be reviewed and adjusted over time, even annually, to meet new challenges and strategic issues. In other words, the end goal or objective may remain largely the same; the route may, however, need to take a detour to meet unforeseen challenges along the way. For example, an organisation's mission may always be to deliver exceptional shareholder returns while maintaining a sustainable social licence, however, the strategic imperatives, near-term goals, time line and way to achieving this may vary over time.

Not all mining organisations define a complete hierarchy of mission, values, vision and strategy. The extent to which these need to be defined and with whom they are shared

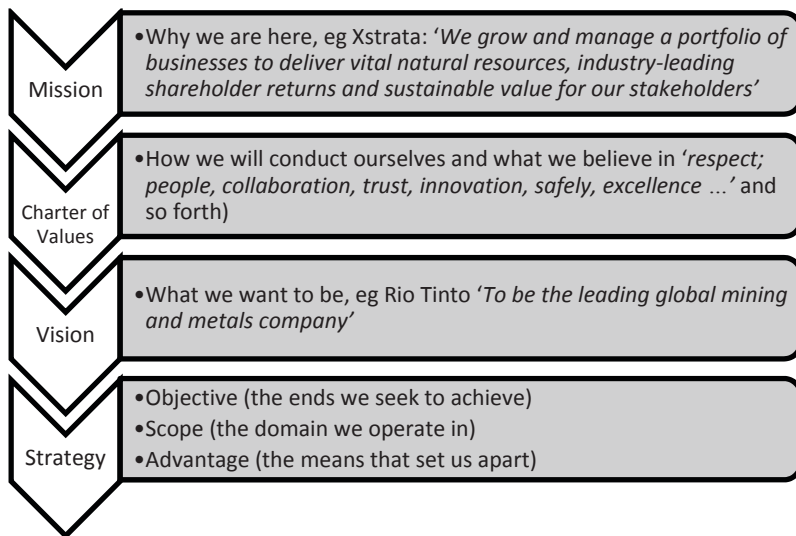


FIG 1.1.1 - Hierarchy of strategic statements.

(publicly or for internal consumption) will be organisation-specific. Many factors will need to be considered, such as scope, scale, stability and anticipated longevity of the mining organisation. The generation of the mission, chart of values, vision and strategy statements are usually the responsibility of the organisation's senior executive team and not the result of an organisation-wide democratic process. While there is a growing understanding and knowledge of what comprises a well formulated set of statements within the senior executive ranks of the mining industry, it is still accepted good practice to have these workshopped either in synthesis or in review using external facilitators. Use of facilitators who know little of the technical detail of the mining industry but a lot about what motivates individuals and what they perceive is highly beneficial and will make the communication and understanding of strategic statements easier as they are cascaded down through an organisation.

It is not uncommon for there to be limited numerical or temporal reference within mission, vision and strategy statements that are shared publicly. Creating a measurable expectation that is not achieved can have a significant impact on investor confidence. For publicly-listed mining organisations the listing authority will have guidelines not only around what can be reported as Reserves and Resources, but also around what can be broadly communicated, particularly if it pertains to growth expectations based on mineral inventories that have not reached recognised standards on quality and assurance.

Whatever the situation, the statement of strategy will need to inspire the stakeholders that are most important to the success of the mining organisation no matter what the scale, scope or tenure of the organisation might be. For the mine to deliver on the strategy it will need to be transformed and scaled to business units and functions as tactical plans and ultimately individuals to focus performance.

The ensuing sections review in more detail some examples of business strategies adopted by mining organisations today. The concept of a charter of values is then discussed. The current trends for defining these and ensuring they mean something to aid an organisation meet its strategic goals and remain a sustainable business is covered.

Next is a discussion of the framework and methodology for transforming and scaling strategy to business units, departments, functions and individuals, prioritising the work that needs to be done to be successful.

Lastly there is no guarantee a journey will end where it is intended unless one monitors progress and responds accordingly. And so this section concludes with a discussion of the methods and approaches that are common for monitoring the implementation of the strategy to ensure the end state is achieved.

1.1.2 Formulation of strategy

There is good reason for an organisation to have a clear strategy. We have the accumulated wisdom of top leaders and strategic thinkers from across the ages and all walks of life to gain inspiration. From enduring quotes such as Sun Tzu (Chinese Military leader, 500 BC) 'Strategy without tactics is the slowest route to victory. Tactics without strategy is the noise before defeat'. To a broad range of modern reference and text books on the latest thinking. Richard R Blackburn: *The Sustainability Handbook: Strategic Planning* (Blackburn, 2007) provides a good summary of why having a clear strategy is important for success. A clear strategy:

- raises awareness about threats and opportunities, helps an organisation confront the brutal reality
- aligns the organisation around a common direction and set of priorities; improves teamwork and job satisfaction
- eliminates low value work
- improves organisational efficiency and productivity
- provides a basis for allocating resources
- provides a baseline and direction for measuring progress
- helps instil confidence in the leadership ability of top managers
- enables all employees to understand the importance of their role in achieving the organisation's major objectives
- brings new ideas to the surface for the benefit of the organisation
- establishes accountability for performance.

In today's world where mining organisations have reached a certain scale and momentum, with a resource base large enough to provide options on how to create value, attentions will turn to strategy. In order to stay in business long enough to develop the resource to its full potential (the expected value) attention will need to be paid to increasingly sensitive issues, with stakeholder groups that have always been there, but historically may not have had the voice or bearing to impact the strategic direction of an organisation.

Addressing these issues and balancing the interests of all the influencing stakeholders is the embodiment of the modern-day concept of sustainability. Consequently, statements on strategy, particularly for larger and enduring mine organisations, will never stray far from recognising that sustainability and all it embodies is critical to achieving strategic goals. Sustainability is scalable and not simply the domain of larger mining organisations. For example: a small single-pit mine of limited life will still need to build a relationship with suppliers, its workforce, regulators and its neighbours. If anything goes terribly wrong with any one of these groups cash flow can dry up quickly and organisation failure could rapidly follow. For large mining organisations reputational damage, if not addressed, can ultimately lead to the same outcome.

Consequently, there is an increasing trend to having functional strategy. This is shared publicly to varying degrees and referred to, for example as 'pillars', 'foundations', 'drivers' that underpin an overall statement of strategy. Typical key areas for functional strategy that align with threats to sustainability include:

- health and safety (of workforce)
- environment and community relations (sometimes referred to as 'social licence')
- human resources (learning and development)
- government relations
- supply chain
- minerals exploration.

Blackburn provides a good overview of the relationship of strategy and sustainability and guides from developing strategic goals and objectives right through to talent management and measuring individual performance.

The following are a selection of statements of strategy taken from publicly-listed mining organisations' web sites during early 2012. These examples and other prominent mining organisations have visionary statements aspiring to be 'the best', 'the most respected', 'the leading', 'the number one' or 'the company of choice'. Their statements on strategy say something (or perhaps not, as not all are spelt out) of what they will be doing to achieve this. In combination they provide some insight as to what sets them apart – what advantage they hope will attract investment and human resources and simultaneously instil confidence in the communities they intend to operate in the pursuit of a sustainable organisation.

XSTRATA

Strategy:

Our strategy to create value for our shareholders and shared benefits for our stakeholders rests on three core pillars:

1. *continuous improvement in the quality of our assets*
2. *organic growth from our extensive pipeline of projects*
3. *growth through mergers and acquisitions.*

Strategic priorities:

- *to deliver a Tier 1 portfolio of projects on time and on budget to increase our production volumes and meet society's demands*
- *to increase the net present value of our business by improving the quality of our assets and by operating safely and efficiently*
- *to maintain our industry-leading standards of health, safety and environmental performance and to be viewed as a responsible partner within the communities in which we operate*
- *to attract the highest potential talent and build the capabilities necessary to deliver our strategy*
- *to foster a high performance.*

RIO TINTO

Strategy:

To invest in and operate large, long-term, cost-competitive mines and businesses, driven by the quality of each opportunity.

Strategic drivers:

Five strategic drivers are helping us deliver our strategy and achieve our vision:

1. *financial and operational excellence*
2. *growth*

3. *licence to operate*
4. *globalising the business*
5. *technology and innovation.*

BHP BILLITON

Strategy:

Our strategy is to own and operate large, long-life, low-cost, expandable, upstream assets diversified by commodity, geography and market. Our strategy has remained unchanged for over a decade and has enabled us to deliver superior margins throughout economic and commodity cycles for many years.

ANGLOAMERICAN

Strategy:

Together the following four elements form our strategy:

1. *investing: world-class assets in the most attractive commodities*
2. *organising: efficiently and effectively*
3. *employing: the best people*
4. *operating: safely, sustainably and responsibly.*

NEWCREST

Strategy:

Newcrest pursues a strategy of delivering competitive shareholder returns by:

- *Optimising performance at each phase of the mining value chain for gold within selected geographic areas (Australia and Pacific Rim). This value chain spans exploration, development and operation of low-cost, long-life gold and gold–copper mines.*
- *Building a portfolio of gold opportunities to convert into operating mines. Opportunities to grow the business include brown and greenfields exploration, combined with a focus on early entry merger and acquisition prospects in known gold regions.*
- *Harnessing technical expertise across a wide range of leading-edge mining formats and technologies.*

1.1.3 Values

Patrick M Lencioni, in his article ‘Make your values mean something’ (Lencioni, 2002) claims that in his experience ‘most values statements are bland, toothless, or just plain dishonest’. Figure 1.1.2 is a values statement word cloud whereby the larger the text, the more frequent the occurrence, taken from the world’s top diversified and gold mining companies as presented on their web sites as of March 2012. They include strong, concise and meaningful words but do they set themselves apart in the eyes of stakeholders and provide a competitive advantage?

Quality in values definition can be used to set an organisation apart, giving it an advantage over competitors (an essential element of a quality statement on strategy). The development of values should not be rushed. Most in industry that have experienced the transformation whereby values have become a cornerstone of corporate strategy will concur with Lencioni, who also states:

... coming up with strong values – and sticking to them – requires real guts. Indeed, an organisation considering a values initiative must first come to terms with the fact that, when properly practiced, values inflict pain.

FIG 1.1.2 - Values statement word cloud: world's top diversified and gold mining companies.

He goes on to say:

Values initiatives have nothing to do with building consensus – they are about imposing a set of fundamental, strategically sound beliefs on a broad group of people.

Core values are those that organisations often take time to develop through formal programs and expert facilitation. These are the values that are sacrosanct and cannot be compromised. For an organisation that strives for its values to mean something, every employee will carefully consider these with each decision they make individually or as a group. They will, in fact, be embedded in everything an organisation does.

In Figure 1.1.1 many of the words used to define values are those that could equally be regarded as the minimum behavioural and social standards required by any employee – ‘trust’, ‘respect’, ‘integrity’. Industry has seen a big push in recent years to ensure the outside world (the general public, affected communities, governments, investors) that sustainability is at the forefront of mine management’s strategic thinking. Hence the predominance of reference to people, safety, environment and social responsibility in values statements. An indication of core values that aim to set one organisation apart from competitors is the infrequency of reference across multiple organisations’ public values statements. In Figure 1.1.2, diversity, simplicity, entrepreneurial and innovative are a few words of note and may resonate with rallying solutions from within to the global challenges the mining industry currently faces as a whole.

Whether rallying a major mining organisation or a ‘junior’ with a single short-life pit with a diverse workforce of owners, staff and contractors, the benefits of having core values defined and a management team with the courage and commitment to see them lived, should be obvious over time. Adverse incidents resulting from cultural and behavioural lapses will reduce. There are the usual lagging indicators in safety statistics (total recordable injury frequency – TRIFs, lost time injuries – LTIs), environmental incidents, workforce vacancy rates and turnover, community complaints and regulatory citations. How one performs on these can differentiate one mining organisation from another but not

always in a positive way – ‘bad news travels fast and others faster still’. The achievement of low incident rates in these areas is expected by all stakeholders; they are, in fact, the ‘permission to play’ or ‘licence to operate’ values, particularly for mining organisations. One should not take an eye off the ball in these areas because the consequences can have a serious impact on an organisation. Incorporation of fit for purpose core value statements is prudent leadership. Discipline applied and habits learned in these areas will carry over to other areas of the organisation as well as to life outside work – who would consider wearing full personal protective equipment (PPE) at work and ‘whipper-snip’ the lawn edges on the weekend at home wearing only flip flops, shorts and a singlet?

Core values that are common to all, irrespective of position and function, do not always migrate and cascade effectively all the way to individual performance tools and metrics. For example, a head office personal assistant who never visits a mine may struggle to impact environmental performance or the safety culture of operations, but may increase the diversity of a workforce and impact profitability by coming up with innovative ways to reduce travel costs. Consequently, quality core values should consider not only those that have big impacts when they are not fulfilled, but also encourage and allow all employees to align with and create measurable value in a positive and leading way.

To succeed in living the core values and impacting the organisation favourably, accidental values that arise spontaneously through the common interest of employees should be managed – encouraged if favourable and mechanisms installed to eliminate if not. For example, providing showers and change rooms for those who exercise to and from work and during breaks should probably be encouraged, while those that adopt a ‘work hard, play harder’ after each shift in the wet mess should probably have curfews and bar counter limits applied.

In summary, when forming statements of core values one should take the following into account:

- Understand why the reasons for defining the values in the first place. Doing it simply because it is fashionable is not the answer.
- Be prepared for hard work. Once defined they must be lived and owned by everyone in the organisation and the consequences for knowingly acting to the contrary understood and applied unequivocally.
- Connect them to the business strategy. Include a mix of values that both reinforce to key stakeholders that their interests are paramount as well as values that will inspire employees to step up and create value in a leading way. Allow the individual or teams to connect their efforts with a material and positive impact on the organisation. Make them a part of all personal performance goals.
- Keep them current. Like anything that is required to endure, core values require maintenance and upkeep. Look for common traps or signs it is time to refresh and refocus, such as poor decision-making or petty foot-faulting between employees.
- Avoid aspirational values and manage accidental values that may arise decisively.

1.1.4 Turning strategy into action

Turning strategy into action is hard work. Good operating practice will ensure not only that everyone understands and believes in the strategic goals but can trace a direct link between their own actions and the ongoing performance of the organisation relative to the strategic goals. Teams and individuals will believe in and take accountability for their actions having

influenced the outcome. In order for this happen, strategic goals and priorities need to be migrated down into the entire organisation, including:

- business units with common domains or scope, for example aligned commodity or an individual operation
- functions across all mines, but perhaps tailored to global regions
- departments (within a mine for example)
- all individuals, from operators, tradespersons and technicians through to senior executives of the organisation).

A common framework to describe the cycle of rolling out strategy, undertaking the work to deliver the outcomes, regularly monitoring performance and then acting should things change is the plan-do-check-act (PDCA) cycle (see Figure 1.1.3).

FIG 1.1.3 - The plan-do-check-act cycle.

MANAGEMENT OPERATING SYSTEM

The management operating system (MOS) is the management processes, metrics and tools that enable leadership to drive the PDCA cycle at all levels. It is a systematic way of planning, executing, monitoring and managing business performance. Many operations by default will have a MOS. The level by which it is systematically applied in a standard process across the organisation may be quite low or not at all.

Having a deliberately designed and well-thought-out MOS is essential in today's mining world, where vast amounts of information flow in real time and shift rotations for remote operations can be short, often with limited overlap of resources. These and other pressures require immense discipline in work habits.

For example, there is no point having a strategic goal to reduce real operating costs if no plan is put in place to actually define the steps and tasks to be undertaken to do this and broken down at all levels to individual responsibility. It is no good saying that this will come about by the mine increasing load and haul productivity and leaving it at that. How exactly? – will it be shovel and truck? Will it be from increasing instantaneous productivity or greater operating hours, or both? Will queue times be the focus or better traffic flow and average haul speed? And who will be responsible for this – operations, planning, maintenance, or everyone? What will the individual task lists be and how and when will performance against the goal be measured? If hang time is reducing and queue time is going up is that a good outcome or a bad one in terms of achieving the goal? Lastly, is this a higher priority than everything else going on or something to focus on only when things are 'quiet'?

Figure 1.1.4 summarises what a typical or generic PDCA cycle might look like to plan and run a mining operation successfully. It contains many cornerstones of planning and work management that have been a feature of mining for many years. Many organisations

FIG 1.1.4 - Generic mine plan-do-check-act cycle.

will have their own nomenclature and a unique rhythm of when and how frequently plans are created, monitored and to what level reforecast and ultimately the cycle repeated. The broad sequence will, however, be the same, with the first step being to take strategic goals and turn them into tactical plans that are optimised for achieving the goals and that increase in resolution the closer they come to being executed.

Each level of a mining organisation, each department and function, should define their own MOS following the same common framework; it is a scalable process.

STRATEGIC PLANNING

The life-of-mine (LOM) plan or schedule generates mining material physical flows of ore, waste and saleable product by year until ultimately depleting the Ore Reserves or Mineral Resource. It is general practice to only work to one LOM plan at a time and so it follows that it is already globally optimised in terms of mining limits, mining sequence, mining and process rate and, consequently, for associated major capital investment, such as for new mine fleet, mine development or infrastructure.

Arriving at a single LOM plan may be obvious if the asset is small; a single product with a small Ore Reserve and Mineral Resource and there are no other operations competing for resources and capital within the same organisation. If this is not the case, then a strategic planning phase will need to be undertaken. This planning should first diverge the thinking, drawing from a broad range of functional experts and not simply the mine planner or planners to generate possible scenarios and also quickly weed out the ones that will struggle or are not material under rigorous cross examination. Finally, this planning phase will test

those that remain to produce an optimised plan or series of plans for different conditions or outcomes for critical decisions. This will generally be done by highly experienced mine planners with strong functional expertise, business acumen and working knowledge of the entire organisation using tools that are designed for the task.

The business plan will most likely be a subset of the LOM plan – the first three or five years are usually a rerun or reoptimisations of the mine schedule to produce the mine physicals on a higher resolution – smaller period, yearly then quarterly for example. The business plan will merge the physical mine plan with department and function activities and costs, head counts, equipment and consumables as well as incorporating detailed project plans and any new initiatives. It is important when any new plan is generated, whereby either its value is calculated in a new framework process or it overlaps the mine schedule generated by an earlier lower resolution plan, that a reconciliation is undertaken to ensure any plan to plan variances are expected.

TACTICAL PLANNING

Tactical plans have an objective of defining 'how' the strategic goals are to be achieved. They include the prioritised tasks, resource and budgets by area, department and function that allow the roll-up to produce the mine or organisation budget for the initial year, or perhaps two years, of the business plan. Various general planning tools will help a mine focus on the traditional top level production performance indicators of cost of production, product sold and capital spend. Such tools include value stream modelling (VSM) and value driver trees (VDT) as seen in Figure 1.1.4. Task prioritisation tools such as those that qualitatively rank and rate value contribution versus cost / resources required / simplicity of implementation can also be applied.

Figure 1.1.5 illustrates a sequence of steps for mine leaders to cascade the organisation's strategy down into the business and into action. As one moves more into tactical planning and defining tasks and actions to achieve the goals, be sure to use the 'SMART' approach:

FIG 1.1.5 - Cascading strategy into action.

- S** Specific: use effective verbs and define the outcome beyond question.
- M** Measureable: what is the deliverable? What does success look like? Can the question 'did we achieve the goal?' be answered with yes/no?
- A** Accountable: has the person responsible agreed to the assignment?
- R** Reasonable: is the assignment achievable and yet tough enough to be a stretch?
- T** Time bound: is there an agreed date for completion?

Figure 1.1.6 is an example of a monthly managers' and superintendents' priorities setting and tracking planner. The planner ensures focus is always placed on the top three projects or initiatives at all times. These will migrate from the department tactical plan containing the top ten priorities that the department will work on during the period defined for achieving the goals, a budget year for example. There are several key elements to the planner:

- it relates the activity back to strategic imperative/pillar/value/driver or foundation – if this can't be done then it is not a priority
- tasks are defined on a 'SMART' basis
- status is simple and concise and the ability to close out tasks (completion rate) is measured
- it must be dynamic – there is no point focusing on a priority set some time ago that for some reason is longer valid or has been superseded by unfolding events
- accountability – tasks are kept prominent each month until they are either completed or deprioritised.

MONTHLY PRIORITIES			DEPARTMENT: MINE OPERATIONS				
Ref. #	STRATEGIC PILLAR	ACTIONS	Top 3?	WHO	BY WHEN	STATUS	
1	Delivery	Top 10 Projects Section	Yes	Responsible	Date	On Track	
2	Lowest Cost		Yes			On Track	
3	Zero SL Incidents		Yes			At Risk	
4		Last months priorities not complete				Lagging	
5						Lagging	
6						Lagging	
7		Common Department Actions					
8							
9							
10		Emerging Issues					
11							
12							
13		Department Tactical Plan Actions					
14							
15							
						Completion Rate:	
DE-PRIORITISE - activities agreed NOT to complete this month							
		Items agreed NOT to do this month					
ACTIONS FROM GENERAL MANAGER 1:1 meeting							
		Priorities emerged During Month					

FIG 1.1.6 - Department monthly priorities planner.

PERFORMANCE MONITORING AND THE BALANCED SCORECARD

When reporting actual performance against plan, the reasons for variance, the longer-term implications (on goal attainment) and corrective actions to be undertaken, use a report format that is clear and concise. A common approach is to use a green, yellow/amber, red traffic light colour scheme to indicate status on initiatives mapped under each strategic pillar.

Figure 1.1.6 has many of the same attributes of a balanced score card, which may only differ in terms of being fixed for the performance period (budget year typically) in terms of the priorities and tasks being reported against for the function, department, operation or even at sector/region/group function level. At the end of the year one expects to see all tasks closed out and the impact defined.

The score card is a tool that aligns the organisation with corporate strategy. A sector or region or group score card will typically (apart from top level production, cost, safety and social licence to operate incident statistics for example) include a report on all the major initiatives the sector, region or group is undertaking and will track performance against these. For example, 90 per cent of all employees will have agreed personal development plans completed by the end of the second quarter.

The score card will have the same look and feel for areas, departments and functions in so far as everyone is responsible for achieving the strategic goals of an organisation and will need to set and prioritise initiative type work that, if completed successfully, will achieve an expected improvement in the areas that matter.

Typical performance monitoring reports for mine operations will accumulate physical progress over time of 'actual versus budget' in numerical tables of key performance indicators (LTIs, TRIs, tonnes mined, development metres, metal produced, community complaints and environmental incidents). It is common practice to also colour-code performance using a traffic light scheme, although with slightly different interpretation than for initiative or task tracking. Green, for example, to show when exceeding budget by x per cent, amber/yellow when meeting budget within a range of $\pm x$ per cent, or red when performance is at risk and lagging budget performance by -x per cent. Figure 1.1.7 illustrates a sample extract of a typical operations weekly report.

FIG 1.1.7 - Extract of a typical mine operations report format.

1.2 PERFORMANCE MEASURES

1.2.1 Occupational health and safety management systems

WHAT IS PERFORMANCE MEASUREMENT?

Measurement of occupational health and safety (OH&S) performance is not a simple matter to define. The Australian Safety and Compensation Council (ASCC, 2005) define it as a measure of the level of effectiveness of those business activities aimed at the prevention of

injury and disease to persons in the workplace. There are a number of questions that need to be answered before selecting the most suitable performance measures for the situation.

First, who is the measurement for? There are a number of stakeholders who will assess the safety and health performance of a mine. There are statutory requirements and corporate requirements. In addition, the measure may be to evaluate the effectiveness of a particular program or correction of poor behaviour.

Then, what is being assessed? Is it absence of injury? Good safety behaviour? Is it benchmarking against others? Is it the potential for harm? In the case of the last assessment a good example would be the difference between undertaking respirable dust monitoring for regulatory purposes, ie to demonstrate that allowed levels are not being exceeded; in comparison to assessing the risk of respiratory illness – this would entail a detailed monitoring regime that characterises the dust exposure of each work environment.

TYPES OF PERFORMANCE MEASUREMENT

In order to assess the effectiveness of the occupational health and safety management system (OHSMS), the performance measurement needs to establish a comparison – before and after intervention or application of a management process. Measures are broken down into proactive or positive indicators and reactive indicators. Positive indicators attempt to measure good health and safety performance and improvements rather than the absence of negative performance. Reactive indicators relate to the potential for harm, either predicting the harm (lead indicators), or assessing the consequence (lag indicators). Ultimately the sustained absence of illness and injury is the measure of success. Interim measures can assess the degree and effectiveness of the implementation of the OHSMS. Often the definition of lead indicators is broadened to include positive performance indicators. The position of each type of indicator in the control process can be visualised using the bow tie model as outlined in Figure 1.2.1.

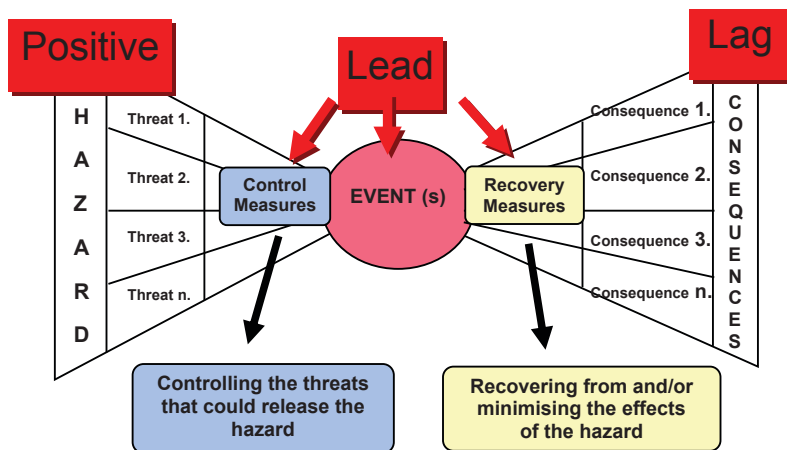


FIG 1.2.1 - Example of bow tie analysis model.

TRADITIONAL REACTIVE INDICATORS

Reactive measures attempt to assess the impacts of an OHSMS and focus on the number, severity and duration of accidents, incidents, injuries and illnesses. They are reactive because they do not directly contribute anything to improving management of OH&S.

Examples of traditional lag indicators include:

- lost time injury (LTI) – an injury that prevents the worker from commencing their next work shift
- restricted work injury (RTI) or disabling injury (DI) – an injury that prevents the worker from commencing their next work shift in their normal occupation
- medical treatment injury (MTI) – an injury requiring medical treatment
- first aid injury (FAI) – an injury requiring first aid
- near miss – an event that has the potential for serious harm
- total recordable injuries (TRI) – usually the sum of LTI, DI and MTI.

There is some variation in the definitions between mine sites.

Government department and industry association annual health and safety reports are full of dissections of these measures by every conceivable contributing causal factor. Ironically, the better the OH&S performance, the fewer of these incidents that occur, and the harder it is to use them to assist in improving OH&S performance. For example: LTI in Queensland have halved in under five years. Typically there are about 300 LTI in Queensland each year. Statistically dividing these into mining sectors, open cut versus underground, and then further into work groups or roster patterns, leaves a handful of LTI where random variation can play as big a part in the analysis as any trend being identified. Another factor that has reduced the LTI being reported is the trend in rehabilitation practice to get injured workers back to work as soon as possible, even if it means on light or alternative duties. This turns what ten years ago would have been a LTI into a disabling injury or restricted work injury and thus it is not reported in the same category, detail or with the same focus. Most mine sites now focus on TRI in order to get sufficient statistics to establish trends and attempt to identify causal factors. The drawback with this is that it weights all injuries equally independent of the severity of the outcome.

Health performance measures are even more problematic, typically relying on worker's compensation data. This requires a doctor to diagnose an illness (including chronic injury) as being work related. In addition the illness normally requires the person to have taken time off work to qualify, often in excess of seven days. Sick leave is not monitored for occupational illness and 'presenteeism' – where a person is actually at work but not working at capacity – is ignored. It is thus likely that health performance is very poorly monitored in the mining industry, resulting in significant under-emphasis on occupational illness.

Care has to be taken in assessing impacts of changes in OH&S management. A premeasurement and one post-measurement do not necessarily prove that the change has had the desired impact or not. The 'Hawthorne' effect is a well-documented case of, 'if people are watching you, performance may change' in any case. Any measure pre or post should be a sustained measure over time, rather than a once-off measure.

LEADING AND LAGGING INDICATORS

As the names suggest, leading indicators provide information about the current situation that will affect future performance, whereas lagging indicators provide information on the outcomes of actions. The main lagging indicators ultimately relate to zero harm – the absence of injury and disease. For example: monitoring noise exposure of workers and reporting the percentage of workers whose noise exposure exceeds the standard would be a lead indicator. Ultimately this would be related to the lag indicator of workers' compensation costs for noise-induced hearing loss.

The push to move to leading or positive indicators has been in motion in Australia since at least 1994 when Worksafe (as it was called then) convened a seminar 'Beyond Lost Time Injuries' (Worksafe, 1994). A number of the papers presented at this seminar highlighted the flaws in using lost time injury frequency rates (LTIFR) as the principal indicator of safety performance. In his paper Hopkins identified three principal reasons:

1. they are far more sensitive to claims and injury management processes than real changes in safety performance
2. in any particular workplace because only a few occur each year, variations from year to year will be statistically insignificant, ie due to random fluctuations and thus no guide to changing levels of safety
3. they tell us nothing about how the most serious safety hazards are being managed; for example, mine fires and explosions cause fatalities but rarely injure people.

StepChange (StepChange, 2001) identified problems with using lagging indicators to include:

- Time delay between the actions taken and the outcomes that result from the actions. The lagging indicator may provide information too late to allow a response.
- Outcomes are the result of many factors and lagging indicators may not explain why a result has occurred.
- The measurement may be low, or infrequent, eg LTI and thus not provide enough information or adequate feedback for effective management.
- The outcome measure is so severe, eg fatality, that waiting for it to happen to find out that the process is going wrong is obviously unwise. The reverse is also true; the absence of fatalities does not necessarily mean that the safety systems are working, as they (the fatalities) occur so rarely.
- Lagging indicators may fail to reveal latent hazards that have a significant potential to result in disaster.
- LTIFR may indicate more about claims behaviour and claims management than actual performance.
- They measure failure not success.

Leading indicators can be used to monitor the effectiveness of control systems and give advance warning of any developing weaknesses before problems occur. A leading performance indicator is something that provides information that helps the user respond to changing circumstances and take actions to achieve desired outcomes or avoid unwanted outcomes.

Potential pitfalls with leading performance indicators:

- there must be an association between the inputs that the leading indicators are measuring and the desired lagging outputs
- there needs to be a reasonable belief that the actions taken to improve the leading performance indicator will be followed by an improvement in the associated lagging output indicator
- targeting the wrong issue
- the selection of leading performance indicators is not sufficiently demanding
- leading performance indicators being seen simply as a metric with actions being taken to get a good score rather than being used to guide actions that will correct weaknesses and improve output performance

- subjectivity in evaluating the leading performance indicator that allows a degree of self-deception
- the failure of improving performance, as shown by leading performance indicators, to be followed by corresponding improvements in associated lagging outputs can result in the leading performance indicator being discredited and being seen as an excuse and an alternative to really improving performance.

The StepChange report (StepChange, 2001) links different safety culture levels with the appropriate type of performance measure. At the compliance level conformity with standards and regulations can be used. At the improvement level the indicators focus on identifying areas of potential for improvement, eg measuring the effectiveness of the implementation of the OH&S management system. In an organisation with a mature safety culture the indicators are customised to each work group as the areas with the greatest opportunity for improvement will vary between work locations and work groups. Each will identify their own improvement actions. The lower level indicators should continue to be used in a mature safety culture to warn of any weaknesses in these areas.

Leading performance indicators have a range of uses:

- identifying what is important for improving performance and increasing engagement in improvement activities
- giving positive reinforcement and direct feedback of the efforts being made to improve performance
- as part of incentive schemes to recognise implementation of activities that will lead to improved performance (the potential pitfalls of incentive schemes will be discussed later)
- providing warning of the health of a process, allowing for corrective action to be taken early
- improving the sensitivity of performance monitoring if the number of output events is low
- provide metrics to monitor industry safety performance or as part of industry benchmarking.

Benchmarking or monitoring industry performance requires the use of indicators that are uniform across the industry.

The characteristics of good indicators include:

- objective and easy to measure and collect
- relevance to the organisation or work group being measured
- providing immediate and reliable indications of the level of performance
- efficient use of resources, including personnel to gather and process the information
- being understood and owned by the work group
- relationship to important activities for future performance
- being able to be influenced by the work group whose performance is being measured
- providing a clear indication of a means to improve performance.

StepChange (2001) recommends the selection of about ten leading performance indicators to provide reasonable cover of the main process inputs. The mix of maturity level indicators selected will vary depending on the maturity level of the organisation – level 1 organisations will only use level 1 indicators, whilst those at level 3 will use some level 1, some level 2 and mainly level 3 indicators.

The key to effective use of leading performance indicators is statistically valid analysis coupled with simple and clear presentation of the information. Sometimes individual indicators are combined to give an overall score to indicate simply whether the work group is improving its performance overall or not. Combining indicators effectively is difficult and is criticised for using good performance in some areas to cancel out poor performance in others.

The ASCC guidance note (Australian Safety and Compensation Council, 2005) outlines eight steps in the process for developing and using positive performance indicators:

- develop a risk profile for the organisation and/or identify OH&S outcomes of concern
- review current arrangements for managing OH&S to identify areas for improvement
- define key OH&S outcomes that are to be achieved within set time frames
- develop core positive performance indicators (PPIs) based upon the areas of focus for improvement
- ensure that the selected PPIs meet relevant essential criteria
- determine how each PPI is to be collected, calculated and the frequency of reporting
- conduct performance measurement using selected PPIs
- monitor and review.

The StepChange report (StepChange, 2001) identifies leading performance indicators for safety and health separately. Examples of indicators for safety are outlined in Table 1.2.1.

In terms of health positive performance indicators some of those suggested by StepChange are outlined in Table 1.2.2. StepChange notes that there are special difficulties associated with health that need to be borne in mind, including:

- the long latency period between exposure and appearance and diagnosis of a work-related disease
- line managers may not be involved in the investigation of causes of occupational ill health in the same way they would for safety
- health performance indicators may require some form of health surveillance and this can be very personal and needs to be handled sensitively.

A proactive measure should assess how well a system is operating. For example, rather than measure the number of job safety observations (JSO) (and set quotas as a key performance indicator – KPI) what percentage of JSO identified corrective actions have been closed out within the specified time?

Too often in an attempt to get rid of the reactive performance measure bogey, one indulges in simplistic proactive measures like, how many audits have been carried out? How many JSOs? How many safety meetings? How many safety-related toolbox talks? These all have their place in terms of assisting in the implementation of an OHSMS but they should not be used as primary KPIs. Too often the box is ticked just to meet the quota. A poor JSO is worse than none at all. Toolbox talks for the sake of it just undermine the safety culture and breed cynicism towards management's OH&S commitment.

Targeted measures are also valid. For example, if using hearing protection is an issue, then the degree of conformance with wearing hearing protection is a measure of the success of any campaign to get people to wear it. Of course, as stated above, this measure would have to be sustained over a number of months and not just immediately after a series of toolbox talks aimed at increasing compliance.

The results of external OH&S audits need to be carefully assessed for validity, eg various schemes offer ratings in terms of stars. These stars are gained from meeting certain criteria

TABLE 1.2.1

Examples of leading indicators of safety performance (StepChange) versus safety culture level.

Level 1	Level 2	Level 3
Has a safety policy been published?	Has the safety policy been adequately communicated?	% of staff with agreed occupational health and safety management system responsibilities and accountabilities
% of legislation addressed by company procedures	Perceptions of management commitment to safety	% of planned training courses completed
% of statutory training completed	Number and effectiveness of senior managers safety tours	% of identified competency gaps addressed
Extent of communications of statutory requirements to employees	Extent to which plans and objectives have been set and achieved	% of equipment safety tests meeting performance criteria
Number of training hours	% planned safety training completed	Number of critical drawings awaiting updating
% of management and supervisor job descriptions that contain specific health and safety responsibilities	Number of risk assessments updated as a result of changes in work scope	Number of safety improvement actions per inspection
% of safety management system	% of manual handling assessments completed	% of jobs for which risk assessment has been carried out
Number of completed monitor/audit/review activities versus number planned	Extent of compliance with risk control measures	% of reduction in exposure to hazardous activities
Number of management safety visits versus number planned	Number of suggestions for safety improvement	% of work site inspections carried out against planned requirements
Trend of non-compliance note from working practices	Number of safety audits planned and completed	% of jobs with hazard assessments
	Safety audit recommendations closed out on time	% of permits to work reviewed and controls found to meet requirements
	Time to implement action on complaints or suggestions	
	Frequency and effectiveness of safety briefings	
	Number of additional control measures identified at site during execution of work	

– based on good OH&S management principles, but often they can have more to do with conforming to a mindset such as adequate numbers of fire extinguisher and rubbish bins rather than safety culture. They can be very useful in motivating mines to improve performance; it depends where in the culture hierarchy they sit, at the bottom, where fundamental awareness needs to be raised and having adequate resources is important, or near the top, where management commitment and transparency can be the major issues.

The Minerals Council of Australia (MCA) report dealing with positive performance indicators (MCA, 2001) lists many types of measures that can be used that relate specifically to the mining industry. The document relates them to the intent-approach-deployment-results-improve (IADRI) model for OH&S performance improvement.

TABLE 1.2.2
Examples of leading indicators for health (StepChange) versus safety culture level.

Level 1	Level 2	Level 3
A health and safety policy has been published and distributed	Whether a health and safety policy had been adequately communicated	% of staff with agreed health-related responsibilities
A health plan had been developed to meet regulatory requirements	Staff perceptions of management commitment to health	% of planned training courses completed
All personnel have been assessed for fitness for work through pre and periodic medicals	The extent to which health-related plans and objectives have been set and achieved	% of jobs with health risk assessments carried out
Health related risk assessments and reassessments as required by the legislation have been carried out and controls installed as necessary	Inclusion of health in senior managers' safety tours	% in reduction in exposure hours for hazardous activities
Maintenance regimes required by legislation are in place	Reduction of health risks at design stage by including standards in purchasing policy	% reduction in use of personal protection equipment as control of source improves
Medics and first-aiders refreshers are done in time	The effectiveness of health-related training	% of toolbox talks with a health element
Necessary health surveillance is in place	Number of health-related risk assessments completed	% of permits to work reviewed and controls found to meet health requirements
	Staff understanding of health risks and risk controls	Number of persons stopping smoking after a health campaign
	Extent of compliance with risk control measures	Change towards healthier eating habits
	Health-related audit recommendations closed out on time	Number of people attending medic for personal health assessments
	Frequency and effectiveness of staff health promotion briefings	
	Medic consultations for health surveillance issues	

As discussed before reactive measures can be manipulated. A lot has been written about the problems of using incentives to attempt to improve health and safety performance.

EXAMPLES OF POSITIVE PERFORMANCE INDICATORS

The latest safety performance report issued by Mines and Energy Queensland (Department of Employment, Economic Development and Innovation, 2012), as shown in Figure 1.2.2, contains a number of examples of positive performance indicators. Two examples are included in Figure 1.2.2. They can be used as measures of the level of progress sites have made in introducing systems – in this case high potential incident reporting systems.

An example of the self-assessment tool for the Health Management Plan (Department of Primary Industries, 2009) is outlined in Figure 1.2.3. At an industry level it allows the

FIG 1.2.2 - The latest safety performance report issued by Mines and Energy Queensland (Department of Employment, Economic Development and Innovation, 2012).

FIG 1.2.3 - Example elements of health management plan self-assessment tool (Department of Primary Industries, 2009).

regulator to estimate the degree of implementation. Tracked over time it can monitor progress and identify sectors that need help or areas of concern. To ensure validity it should be supported by spot checks and audits by Department of Primary Industries (DPI) officers.

BENCHMARKING

In general there is little use of leading performance indicator data for industry benchmarking. There is much potential for this, especially in the areas of exposure monitoring. Risk assessments and hazard identification processes would benefit significantly from improved industry data.

SUMMARY

Safety and health performance measurement is clearly not a simple or a trivial exercise. A range of measures should be developed appropriate to the needs of the site aimed at monitoring effectiveness of key elements of the OHSMS (linked to positive or leading indicators) as well as overall performance (linked to reactive or lagging indicators). Performance measures need to be selected that are appropriate to the maturity of the safety culture at the mine site. As with all other sections the key is review and revise as necessary.

1.2.2 Environment

Environmental management is an increasingly important aspect of mining and is likely to become even more so in future years as mines increase in size and complexity. Managing the environmental aspects of a modern mine is a multi-disciplinary task that requires the coordinated efforts of many operational staff, including process plant operators, mine planners, geologists and mining equipment operators. The mine manager is the key contributor to successful environmental management at most mines by promoting environmental awareness and astutely allocating resources to this increasingly important area of management.

To undertake this task the mine manager needs information, systems and support similar to that listed below, most of which is more fully discussed in Chapter 3:

- Corporate environmental policy statement.
- A full understanding of the environmental conditions that apply to the particular operation. These may be specific conditions placed on the mining lease or license as part of the government approvals process or more general environmental legislation, such as noise abatement or water quality discharge regulations.
- A management structure that defines the responsibilities and authorities of all employees regarding the environmental aspects of the operation.
- A copy of the project's environmental impact assessment.
- An assessment of the environmental risks relating to the project and the methods of mitigating those risks.
- Environmental management plans for aspects of the operation considered to potentially pose high environmental risks, such as acid and metalliferous drainage (AMD) and tailings management.
- Access to suitable technical advice, which may include a mixture of directly employed specialist staff and external consultant/contractors.
- Environmental training programs for all staff and contractors, tailored to their specific roles in the operation.
- A suitable audit regime.

With information, systems and support such as this a mine manager can integrate most environmental matters into the more traditional areas of mine management, such as timely production of quality product and cost minimisation.

Developing a mine culture that sees environmental aspects of the operation as a ‘mainstream’ activity and not an ‘optional extra’ is a major step towards having an environmentally well managed operation.

Performance indicators relating to environmental management can include:

- having the up-to-date environmental policy displayed on notice boards throughout the mine site
- recording progress on environmental matters discussed at operations meetings
- setting suitable KPIs for the workforce in areas such as tailings storage facility management (inspection reporting), mine planning (waste handling), geological information gathering (AMD potential of wastes), mine operations staff (progressive rehabilitation performance) and environmental audit reporting
- establishing a register of staff and contractor training relating to environmental aspects of the operation
- recording stakeholder briefings on environmental aspects.

It should be noted that all of the performance indicators will need to be developed on a site-specific basis as each mine is unique and will require its own specific environmental management strategies and systems.

1.2.3 Employee performance

The common performance measure for any employee, regardless of status or seniority, is a formal process of performance appraisal, dealt with in more detail in Section 5.6 of Chapter 5, where a performance review system (PRS) is presented.

The primary goal of the performance review system (PRS) is to ensure business objectives are achieved, and the method of achieving them is aligned with the values of the organisation and consistent with legislative requirements. The PRS has a critical human resources dimension as it endeavours to maximise the use of human resources to deliver business outcomes, and to grow and develop human and organisational capability so that outcomes can be achieved more efficiently over time. The key dimensions of this system include processes related to objective setting, expected values and behaviours and individual development and feedback.

The PRS answers the following questions:

- *What* do I have to achieve?
- *When* do I have to achieve it?
- *What* resources are available to me?
- *How* am I going to achieve it?
- *How* am I doing?

The strategies developed to address these questions and enable an organisation to achieve its objectives will be presented in Section 5.6 of Chapter 5.

1.2.4 Stakeholder performance

Despite what the title here might suggest, this topic is about measuring the operation’s performance in terms of external stakeholder perception. In this section, it will therefore be assumed that employees of the organisation being managed are not external stakeholders.

In Chapter 4 of this handbook it is suggested that the external stakeholder groups fall into three categories:

1. community relations
2. traditional owner relations
3. third-party relations.

How to measure one's performance under each of these categories is suggested below.

COMMUNITY RELATIONS

It is suggested that each stakeholder in the regional community be identified, and a contact log with that person or persons be maintained. It is also suggested that a record be kept of all the communications with that person as well as a record of all documentation made available to them. Typical stakeholders would normally include bodies such as:

- the Shire Council
- the local school
- local businesses
- community interest groups
- emergency services and police.

TRADITIONAL OWNER RELATIONS

'Traditional owners' is a generic term that is taken here to mean:

- the true land owners (who may live elsewhere)
- the occupiers of the land (who may be of a different indigenous grouping)
- legal advisers to the above
- regional land councils and owner representative groups.

If one's mining operation is subject to a registered native title agreement (NTA), then performance of the operation may easily be measured against the requirements of that agreement, which are most usually set out in point form.

In the case where there is no formal NTA, the measuring the operation's performance is more subjective, but an approach similar to that outlined under Community Relations would be a sensible starting point.

THIRD-PARTY RELATIONS

Third parties in this context, are assumed to include any or all of the following bodies:

- government at state and federal level
- regulatory authorities
- shareholders
- lenders
- suppliers
- customers
- regional landowners
- members of the public.

It is not intended here to prescribe a performance benchmarking process for dealing with each of these stakeholders. Obviously, though, the approach taken with each will be dictated by the nature of the contact and the context of the relationship itself. Whatever the case, however, a structured and thoroughly documented approach should be adopted, not dissimilar to the logbook approach suggested earlier, in the case of community relations.

For additional guidance on this topic, readers are referred to Chapter 4 of this handbook.

1.2.5 Production

Production is the process whereby mining activities combine to transfer *in situ* mineral and rock to either the run-of-mine pad or waste dump. Production involves a large number of mining activities, many being sequential and interrelated, and the performance of each activity impacts on downstream activities. For example, drilling and blasting practices impact on other areas, such as loading rates, truck damage, comminution cost and throughput, waste dilution and ore recovery. It is important that the performance measures in place are holistic and allow managers to drill down into the underlying drivers of production performance.

PRODUCTION PERFORMANCE MEASUREMENT

The broad range of production measures must cover the key drivers of performance, being compliance with the mine plan, physical material movements, mechanical availability (the time equipment is available to work), plant and equipment utilisation (the extent to which installed mining capacity is utilised), and operational efficiency (how productively plant and equipment is used when operating using productivity measures, such as metres drilled per operating hour). In addition it is essential that the underlying reasons impacting on the installed capacity's ability to work and achieve the organisation's goals are understood. This can be achieved by measuring time usage, and monitoring ore stock movements and quality related measures, which link production to value.

The purpose of production (and each mining activity) is to add value, not to achieve maximum efficiency, and trade-offs are involved. It is important to realise that each activity is part of a larger system. To optimise this system will not always allow maximum efficiency of each individual activity but a combination of shifting bottlenecks and adjustments of each activity. High performance is primarily achieved by ensuring that an optimised mine plan, which is both practical and achievable, is in place and is being efficiently implemented. Ultimately the goal of production should be to deliver the physical targets (ore tonnes and grade, waste development, backfill, etc) in accordance with the mine plan and within the cost and other constraints set out in the business plan. In addition, the mine's ability to deliver its future key performance targets should not be compromised. Therefore, a key performance measure is to routinely and regularly compare production performance to the mine plan (this analysis must include spatial reconciliation, as where the material was mined is equally as important as how much material was mined) to ensure compliance.

To establish production performance measures it is helpful to consider all the mining activities in a holistic way. Figures 1.2.4 and 1.2.5 set out the generic production process for open pit and underground mines respectively.

The actual production process will differ somewhat from one site to another and consequently the key components comprising the mining activities and the ore stocks (tonnage and grade) need to be developed specifically for each site.

There is often limited ability to introduce substantial stockpiles to buffer against ore shortages within the production process. Buffers between production activities enable disconnecting one from another, an example is stockpiling between the pit and crusher, which allows mining to continue if the crusher is unavailable. The main objective of the production measures should be to identify how all the parts of the process come together to drive overall performance. Consequently, monitoring ore stocks and managing critical activities that can constrain throughput by maintaining adequate mining capacity to meet short-term high demand and stockpiling is critical to achieving high performance.

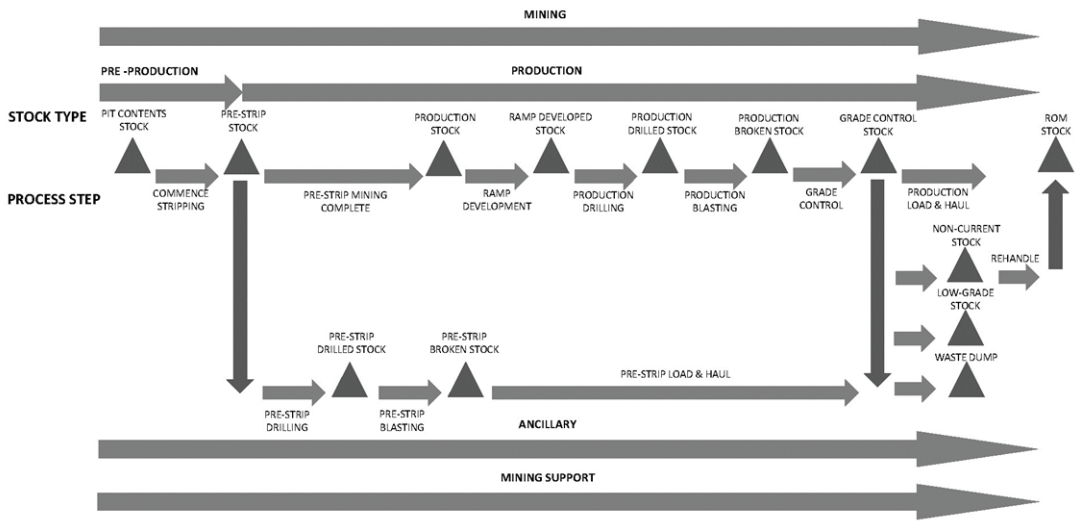


FIG 1.2.4 - Open pit production activities.

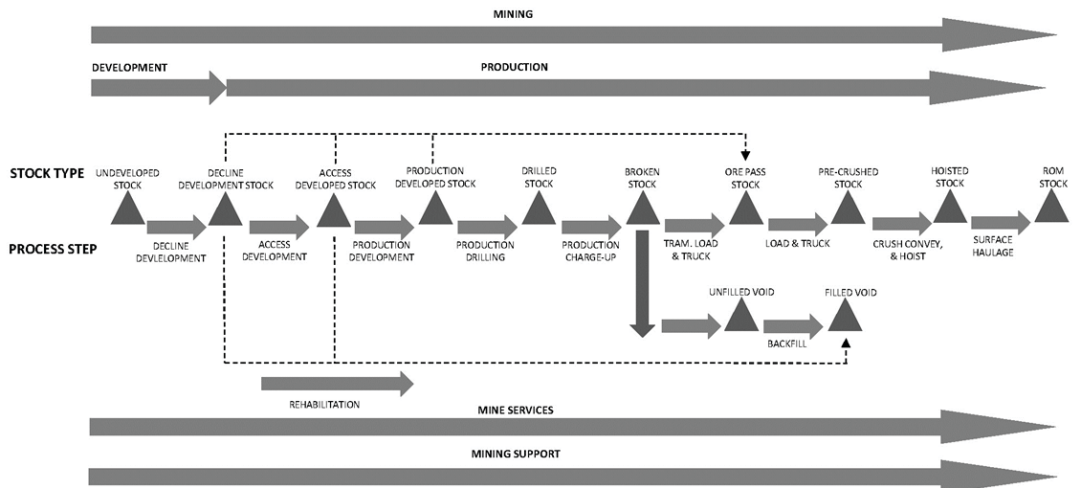


FIG 1.2.5 - Underground production activities.

Standard definitions for each performance measure must be clearly defined and rigorously applied to ensure they are transparent and well understood, and routinely reported to ensure the information is readily available and can be used effectively. This will ensure that appropriate actions can be put in place to address underperformance. There are numerous definitions used for common performance measures across the industry so care must be taken, especially if benchmarking comparison (described below) against other mine sites is to be undertaken. In addition, simulation software can be used to identify bottlenecks and gain an understanding of the reasons behind good and bad performance.

Ultimately, a good production performance measuring process will:

- include a definitive list of clearly defined measures and metrics that drill down to the fundamental drivers of production performance
- link the mine plan and organisation goals in a clear and explicit manner to production performance

- routinely and regularly report production performance and its compliance to the mine plan, including actions required to close any performance gaps.

BENCHMARKING

Benchmarking is an effective technique used to improve production performance by initially identifying gaps between current performance and industry best practice, and then identifying the reasons for underperformance.

A thorough and comprehensive production benchmarking program must adhere to a rigorous and structured process, comprising the identification of superior performing mines and visiting these sites to gather information, data analysis, reporting of results and implementation and ongoing monitoring, as depicted in Figure 1.2.6. To be most effective the strategic goals should be incorporated into the benchmarking process to ensure that the implemented solutions will add value to the operation.

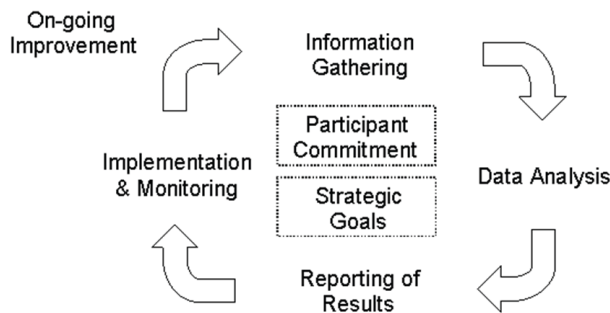


FIG 1.2.6 - The benchmarking process.

For the benchmarking analysis to be meaningful, comparisons must be made on an ‘apples-to-apples’ basis. Data must be collected at a fundamental level, costs at the lowest level they are compiled on site and physical data at the level it is recorded. The data gathered must be compiled into standard formats, and metrics developed that reveal the underlying drivers of high performance. The metrics used must be clearly defined and suitably detailed to ensure comparability. And to be successful the benchmarking analysis must identify the reasons for superior performance. Consequently, the benchmarking team must comprise adequate skill and expertise to identify and understand the superior performance so that it can be adopted, and the team conducting the analysis must be able to act independently to remove personal perception and bias from the results.

Benchmarking requires a significant commitment from all stakeholders and adequate resources must be allocated to the project for it to be successful. The most important aspect to a successful benchmarking process is knowledge sharing, so the underlying practices responsible for superior performance can be identified and implemented.

1.2.6 Capital management

Capital spending management can differ depending on the context of the capital project. For example, with a new project, capital spending might be considerable (exceeding \$1 million per month), in which case there is usually a project manager for that specific project and separate reporting systems for the project as it progresses. Alternatively, within an established operation, capital management might refer merely to the management of the

operation's approved capital budget. Admittedly, this might still be significant, but the mine management financial reporting systems as described in Chapter 8 of this handbook should address that situation.

The particular situation dealt with in this section is the capital expansion or capital addition to an existing operation – where there is no project manager as such and it is the role of the mine manager to oversee and report on the work. In this scenario, the manager may well be advised to introduce a separate management tracking and reporting system for the capital project and continue with it until the end of the commissioning or handover period.

Assume that there is an approved feasibility study, all construction approvals in place and an approved budget for the project. Day-to-day operations at the mine are assumed to continue until the point of handover, at which point the operation will have an expanded capacity, a new producing area, product or the equivalent. So the issue comes down to, 'How to manage an internal capital project within the mine operation?'

It is suggested that the starting point is a detailed task-by-task execution schedule, covering as many of the key tasks as can be envisaged, and gradually expanded as the complexity and interrelation of tasks emerges. A variety of computer software options are available for this, although most mines will already have a pre-existing scheduling capability.

PROJECT SCHEDULING AS A MANAGEMENT TOOL

It is advisable to schedule each major activity first; then schedule the subordinate tasks related to each major activity.

An illustrative example of the identification and arrangement of key tasks is set out below, showing both the key task areas and subordinate tasks:

- project approval
 - board approval
 - project funding
- staffing and recruitment
 - appoint project manager
 - operations manning
 - administration staffing
- capital purchasing
 - major equipment orders
 - major equipment delivery
 - major equipment commissioning
- equipment list
 - tanks and pipes
 - other items
- major contracts
 - sign contracts
 - finalise site layout
 - preliminary earthworks at mine site
 - mobilise on site

- logistics
 - power supply
 - water supply contract
 - road access
 - accommodation
 - communications
- product despatch and sales
 - transport contract
 - sales contract
 - independent assay
- occupational health and safety
 - policies and procedures
 - interface with existing operations
- environment
 - regulatory approvals
 - monitor and report
- finance and administration
 - chart of accounts
 - management reports
 - general administration
 - monthly report
 - joint venture liaison
 - policies and procedures
 - job descriptions
 - recruitment
 - payroll
- commissioning
 - vendor erection on site
 - testing and handover
 - dry commissioning
- start-up.

Once the project execution schedule has been developed in sufficient detail, each task should be allocated the following:

- an estimated start and finish date
- a responsible officer to complete the task
- an estimated total cost for that task.

A contingency should always be included for each capital subheading, if not for the whole project. Depending on the level of engineering detail supporting the capital budget, the contingency may be anywhere between ten and 30 per cent of the total job cost, though usually closer to the former for a definitive, or 'bankable' estimate.

When estimating the cost for a project, product or other item or investment, there is always uncertainty as to the precise content of all items in the estimate, how work will be performed, what work conditions will be like when the project is executed and so on.

These uncertainties are risks to the project. Some refer to these risks as ‘known-unknowns’ because the estimator is aware of them, and based on past experience, can even estimate their probable costs. The estimated costs of the known-unknowns is referred to by cost estimators as cost contingency.

AACE International, the Association for the Advancement of Cost Engineering (AACE International, 2007), has defined contingency as:

An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs.

Contingencies are not intended to allow for scope changes, force majeure events, management reserves, escalation and currency effects. A key phrase above is that it is ‘expected to be expended’. In other words, it is an item in an estimate like any other, and should be estimated and included in every estimate and every budget. Because management often thinks contingency money is ‘fat’ that is not needed if a project team does its job well, it is an often a controversial topic.

PROJECT MONITORING AND REPORTING

The detailed project schedule may now be interfaced with the project capital budget. This will immediately reveal cost items missed in the feasibility study phase and may require an early budget revision if the omissions are many or significant. Once completed, however, the two documents will provide the foundation for the monitoring and control process via the schedule updates and the project cost reports respectively.

In this manner it ought to be possible to present a project completion percentage for each task area and a cost variance report on a regular basis.

To aid this process, it is recommended that the project team meet on a regular basis, ensuring team members are aware of project critical issues, or project changes to scope. Pivotal in this process is the project manager, who would ordinarily report upwards monthly, whilst interacting daily or weekly with the project team, depending on its size and complexity.

In the scenario where the project manager is also the mine manager, this may be difficult to achieve in practice. The size of the project will determine how this potential conflict is dealt with, though the management principles will be unchanged.

1.2.7 Operating costs

Operating costs can be defined as the expenses that relate to the day-to-day operation of the mine. There are two broad categories of operating costs: fixed and variable. Fixed costs are operating costs that do not change relative to production, at least in the short term. Variable costs are operating costs that change relative to production or other drivers of throughput. A third operating cost that is helpful in understanding cost behaviour is semi-fixed or step-fixed costs, which change relative to threshold levels of production. The three types of operating cost are shown in Figure 1.2.7.

Most *mine accounting systems* are established for financial accounting and high-level management reporting purposes and while they facilitate the efficient preparation of cost reports they do not necessarily provide adequate information for the day-to-day management of operating costs. *Management cost reports* should assist managers in reviewing and understanding performance and taking action on an ongoing basis.

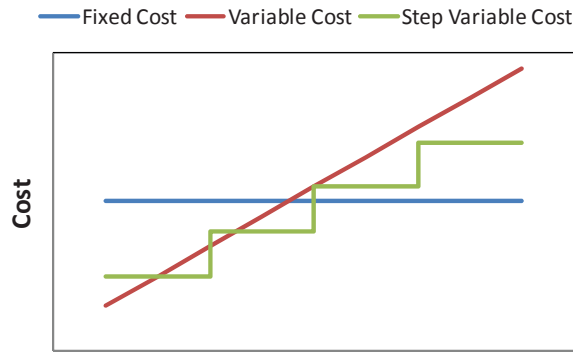


FIG 1.2.7 - Operating cost types.

For management purposes the cost structure can be divided into meaningful areas. Cost departments including administration, geology, mining, metallurgy and engineering are typically used. Costs are then divided into the various functional centres. For open pit mining this may include drill, blast, load, haul, ancillary (including road, floor and dump maintenance, drilling support, etc) and mine services (lighting, dewatering, etc). Costs are then divided into their fundamental cost elements, typically comprising operating labour, consumables and contracts, fuel, power and maintenance (labour, parts and contracts). The cost centres for an underground mine may include lateral development (face drilling, charge-up and ground control), vertical development (rise drilling and charge-up, raise bore) production (drilling and charge-up), materials handling (loading, trucking, underground crushing, conveying and hoisting and surface transportation) and mine services (ventilation, dewatering, water supply, road maintenance, power reticulation, compressed air, service/reticulation holes).

A spreadsheet model of the operation allocating costs to fundamental mining activities and linking them to cost drivers (fixed, step-fixed and variable costs) is an extremely powerful tool in evaluating the outcome of various management alternatives.

Cost reports are only as good as the established cost structure described above and data recording system. There is a cost involved in recording information both in planning and implementation. It requires dedication from supervisors and management to ensure that costs and their physical drivers are accurately collected and cost allocations are appropriate and representative. Additional time and effort is required to ensure analysis of production and cost performance is holistic and identifies actions that will add value as described in the following section.

1.2.8 Shareholder value

Many mining companies state their primary business goal is to 'maximise shareholder value'. There are a number of measures used to depict shareholder value. The most widely accepted being net present value (NPV); other measures may include the internal rate of return (IRR), accounting profits (eg earnings before interest and taxes – EBIT, earnings before interest, taxes, depreciation and amortisation – EBITDA, etc) and accounting returns, based either on total assets (or capital or funds employed) or on shareholders' equity (net assets) (eg return on funds employed – ROFE, return on capital employed – ROCE, return on net assets – RONA, etc). Low unit cost measures, such as cash costs, and achievement of output targets, such as the metal produced, are also common measures.

The ability to influence project value reduces significantly as planning progresses and decisions regarding project parameters are made. During the feasibility study stage one of the main aims should be to evaluate a wide range of options in order to select the best for more detailed further study. Consequently, the project should have been optimised during the strategic planning process, taking into account all of the parameters under the mine planner's control, including cut-off grade, production rate, mining method, mining sequence, production schedule and process design to ensure the mine plan selected best delivers the organisation's goals. It should be noted that as the mine develops throughout the project life cycle more accurate and up-to-date information will become available, which may invalidate past assumptions and outcomes, and consequently the strategic plan needs to be periodically and regularly reviewed and, when necessary, amended to ensure it is still optimal.

Ultimately, shareholder value will be maximised through the efficient delivery of the optimised strategic plan. Thus the short-term tactical mine plan and the mine operations should be working within the framework of an optimised long-term strategic mine plan. Occasional deviations from the strategic plan are a reality in mining, but operations and short-term plans should be seeking to return to the optimum strategic plan.

1.3 STRATEGIC ISSUES AND BUSINESS OPTIMISATION

1.3.1 Strategic threats

Strategic issues will continually arise and challenge operations to deliver on plans. These will come both from within an operation, such as intrinsic issues related to the orebody, and from external pressures beyond the immediate control of the operation.

Lower grades, increased deleterious elements, rising strip ratios and increased transportation and infrastructure costs are common over time and, left unattended, may result in an unprofitable operation, particularly when commodity prices fall.

The availability of skilled people, securing energy, supply chain competition on critical consumables, such as truck tyres and mining equipment, can all have significant implications on an organisation's ability to grow or even to simply remain profitable. A supply chain alliance in vogue one day to secure loyalty, favourable pricing and continuity of supply can concentrate technology (a potential risk) and build up inertia to change.

Community pressures and regulatory authorities can delay permits and impose increasingly restrictive operating conditions. Governments can introduce global policies on such things as emissions, closure bonding, taxes and royalties, all aimed at increasing rents and reducing mining legacy risks.

The ability to expand in boom times may also create pressures: 'a rising tide floats all boats', placing pressure on the capacity of engineering, construction, original equipment manufacturers and regulators to deliver in a timely and cost-efficient manner. And that is before sourcing people to run the operations successfully.

IDENTIFYING EXTERNAL ENVIRONMENT STRATEGIC ISSUES

Many external organisations and institutes provide services and insight into the current nature of risk and threats of a strategic nature impacting the mining sector. Table 1.3.1

lists Ernst & Young's view on the mining sector's top ten strategic business risks for 2009 and 2010.

These can be grouped in numerous ways. For example, by macro threat, sector threat and operation threat or by function: strategic, financial, compliance, operations, as illustrated by Figure 1.3.1.

TABLE 1.3.1
Top ten strategic business risks (previous year's ranking shown in brackets).

Ranking	2009	2010
1	Cost containment (6)	Capital allocation (17)
2	Industry consolidation (2)	Skills shortage (6)
3	Access to capital (new)	Cost management (1)
4	Maintaining a social licence to operate (4)	Resource nationalism (9)
5	Climate change concerns (5)	Maintaining a social license to operate (4)
6	Skills shortage (1)	Infrastructure access (7)
7	Infrastructure access (3)	Access to secure energy (8)
8	Access to secure energy (9)	Access to capital (3)
9	Resource nationalism (8)	Price and currency volatility (11)
10	Pipeline shrinkage (10)	Climate change concerns (5)

FIG 1.3.1 - Strategic business risks 2010 (Ernst & Young, 2010, reproduced with permission).

Looking even further into the future, and to the strategic issues the mining industry may face, the World Economic Forum (WEF), in collaboration with the International Finance Corporation and McKinsey and Company, has published as part of its World Scenarios Series: *Mining and Metals Scenarios to 2030* (World Economic Forum, 2010). This has focused on what the environment for the global mining and metals sector might look like in 2030, drawing on the expertise of experts from the industry and from various relevant stakeholders

and interested institutions. The World Economic Forum web site (www.weforum.org) has a number of publications that would have direct relevance for a mining organisation intending to advance responsible mineral development across the globe and particularly in poorer countries that have a rich mineral endowment.

IDENTIFYING INTERNAL STRATEGIC ISSUES

Internal strategic issues that have a direct and near-term impact on performance inside the mine gate will be identified through many of the usual rigorous business processes deployed as part of the organisation's management operating system. Strategic and life-of-mine planning, Resource and Reserve estimation, business planning and department operational reviews will identify trends on product grades and qualities, performance and cost trends, availability and utilisation of personnel and equipment.

QUANTIFICATION AND MANAGEMENT STRATEGIC ISSUES

The quantification of impact of strategic issues on the value of an organisation is usually handled by a number of key processes. A risk (and opportunity) evaluation, as suggested in Chapter 7 will rank those risks (and opportunities) that have the potential to impact the organisation the most. This process is useful for discrete risks that have the potential to interrupt the organisation in an abrupt manner. The process will identify any additional controls that may be required and the expected reduction in exposure and consequence should the event occur. The outcome of the risk assessment may well be to launch specific initiatives aimed at controlling the risk or putting in place contingency plans.

Where strategic issues present as constraints on the mining organisation, for example hours of operation near a local community or limitations on disturbed land footprint, or where operating performance and markets are indicating divergent trends (to current assumptions) strategic reoptimisation will be required. Usually this will involve mine planners using information on estimated forward trajectories and submodels generated by departments and functions that are the owners of the key business drivers. The mine planner will utilise the appropriate processes and tools to re-estimate mining geometries, recoverable product and mine schedules of product, waste, people, equipment and consumables such that re-evaluation of the organisation's value can be undertaken. The tools for this are discussed in Chapter 10.

1.3.2 Strategic optimisation

Once one understands the risks (and opportunities), the constraints placed on an organisation and the possible options for enabling a solution, the mining organisation or parts of it, will require optimisation. This may or may not involve mine planners running strategic mine planning tools as outlined above, if it does it is usually at the end of the process utilising all available information unless simply undertaking what-if scenario modelling.

It is increasingly more common for the larger mining organisations to include two functions that are a feature of modern day mining. These are the technology and continuous improvement or business excellence functions.

CONTINUOUS IMPROVEMENT AND BUSINESS EXCELLENCE

For projects that are less of a business interruption risk and more of an opportunity for improvement, continuance improvement programs utilising a six sigma style approach are

common practice. With any program that requires additional human resources to be added to mining overheads, care should be taken to not oversell the potential benefits or to claim credit for work not directly shown to be a consequence of their intervention. The benefits to be derived from increasing headcount to manage improvement programs must exceed the cost in time of those in the operations to educate them.

TECHNOLOGY

Industry is increasingly moving towards technology to enable solutions to strategic issues. If people availability and their safe keeping is an issue, automate. Where value can be had by real-time turnaround of information for correct routing of materials and allocation of resources, go wireless with high precision global positioning and so on. Perhaps the strategic issue can only be solved by development. For most companies the first question on technology is usually to define the technology strategy itself. Is it leading edge – innovator, early adaptor, fast follower or use of technology proven by others only? What is the role of the technology department? Is it a watching brief only, does it undertake research (internally or externally or both? Does it develop and pilot or is that by others? Is information technology included and if not what are the battery limits? These questions as well as others will need to be answered in a way that is most likely unique to each mining organisation driven by, in part, the issues that need addressing. How well industry understands an organisation's position and strategy on technology will also be important in ensuring industry comes to the organisation.

COMMERCIAL OPTIMISATION

One of the biggest commercial optimisation questions will involve how much and what do I do myself as an owner operator and how much and what do I contract out to service providers? There is no quick answer. Traditionally, contractor mining has found favour in remote operations with shorter-life operations or for peak load activities such as prestripping waste. The mobile nature of the contractor workforce and the avoidance of having to employ and then retrench, particularly if the workload is not enduring, has been worth the premium paid on services. Similarly, ownership of equipment can be spread over a larger volume of material than perhaps the mine or task has and so, while charged at a premium, contracting can economically outweigh excess capital on the balance sheet.

The traditional model for contractor mining has come under pressure particularly with larger mining organisations. No longer can an organisation's reputation be isolated from that of the contractor. Everyone must adhere to the same values and will be judged accordingly on safety, environmental care and social licence. The lack of availability of resources in recent years has seen mining organisations competing with contractors for the same resources (people, equipment and consumables). Operational performance and control of the organisation is critical and this is forcing some to rethink their strategy. With owner mining follows a decision on the best maintenance strategy for the mobile fleet. Maintenance and repair contracts (MARC) with the original equipment manufacturer's dealership or distributor in preference to self-performed maintenance has been common with larger mining organisations, particularly within Australia. This trend is starting to change. While the factors that influence which approach to adopt are varied according to the situation, it is clearly a function that requires critical skills. Kirk (2000) provides a good comparison and discussion of the trade-offs between MARC and self-performed maintenance.

1.4 MINE ORGANISATION AND MANAGEMENT

This section begins with some general comment on mine management perspectives, followed by some basic organisational theory. This material was first published by Donald Sloan¹ in 1983 who, in his textbook, provides additional reading on this topic, which is highly recommended.

Sloan describes the duties and responsibilities of managers as follows.

Mechanics (no human dimension):

- forecasting (what the future holds)
- planning (dealing with the future)
- organising (who is to do what).

Dynamics (dealing with people):

- commanding (getting it done)
- coordinating (directing people interaction)
- controlling (identifying deviations from the plan).

Sloan also refers to the decision time span in the people context, where he makes the following observations about decision time span and job function, as set out below:

- foreman (days or hours)
- mine superintendent (weeks or days)
- mine manager (months or weeks)
- general manager (years or months).

The following sections will cover some basic organisational theory. Sloan described two basic models, both of which are reproduced here: a function-based structure and a divisional-based structure.

1.4.1 Functional organisation structure

A 'one mine' organisation usually has a functional structure, with a specialist heading each function and reporting to a mine manager (Figure 1.4.1). As the organisation gets larger the same structure can be retained (Figure 1.4.2) or a divisional structure developed (Figure 1.4.3).

The advantages of the functional organisation are:

- it facilitates specialisation
- it facilitates coordination within a function
- it promotes economy of operation
- it allows economic flexibility
- it makes best use of available skills.

Functional organisation structures may exhibit shortcomings as the organisation grows and a case may be made for a divisional structure instead. What are the warning signs? The first signs are usually excessive centralisation, delays in decision-making, difficulties in coordination between functions, managerial deficiencies and difficulties in establishing controls. Sloan recommended that when all of these shortcomings beset the organisation, it is time for a change to a divisional model, described in the next section.

1. Sloan, 1983. Material reproduced with permission.

FIG 1.4.1 - A simple functional organisation structure for a 'one-mine' company.

FIG 1.4.2 - An expanded functional organisation structure for a 'multi-mine' company.

FIG 1.4.3 - A simple, divisional organisation structure.

1.4.2 Divisional organisational structure

A divisional structure is a means of dividing a large functional structure into smaller, flexible management units (Figure 1.4.3). This can enable the organisation to recapture some of the advantages of a small functional structure, whilst minimising the disadvantages that come with increasing size, diversity and dispersion. For example, the divisions might be based on geographical boundaries, different commodities or any other clear business unit distinctions.

Factors in favour of this structure include:

- size of organisation
- nature of the business
- economic trends
- political trends
- management philosophy
- nature of the individual management functions.

Advantages of this structure may be summarised as follows:

- executives are nearer to the point of decision-making
- efficiency may be increased
- decision quality may improve
- headquarters staffing and cost can be reduced
- coordination requirements reduce with increased divisional autonomy.

Disadvantages offsetting the advantages include:

- lack of uniformity of decisions
- inadequate utilisation of the organisation's specialist knowledge
- potential for lack of utilisation of all equipment and executive capability in the field.

In a divisional organisation, functional decisions are decentralised to the mine, hence giving rise to the concept of the 'decentralised organisation'.

1.5 THE MINE MANAGER AS A LEADER

In this section comment will be made on the concepts of ethics and leadership. This is followed by some theory on team building, how teams function and how to build effective teams.

1.5.1 Acting ethically

Ethics, when used as a noun, may be defined very broadly as that branch of philosophy dealing with values relating to human conduct, with respect to the rightness and wrongness of certain actions and to the goodness and badness of the motives and ends of such actions.

In the professional context, however, a narrower interpretation may be applied, suggesting the rules of conduct recognised in respect to a particular class of human actions or a particular group, culture, such as AusIMM members or minerals industry professionals.

This narrower interpretation has given rise to The AusIMM Code of Ethics (The AusIMM, 2007), which, of itself, sets out what constitutes acting ethically. Put simply, ethical behaviour embraces the following principles:

- the responsibility of mine managers for the welfare, health and safety of the community shall as a general principle come before their responsibility to the profession, to sectional or private interests, or to other mine managers
- mine managers shall act so as to uphold and enhance the honour, integrity and dignity of the profession
- they shall perform work only in their areas of competence
- they shall build their professional reputation on merit and shall not compete unfairly
- they shall apply their skill and knowledge in the interests of their operation(s)
- they shall give evidence, express opinions and make statements in an objective and truthful manner and on the basis of adequate knowledge
- they shall continue their professional development throughout their careers and shall actively assist and encourage those under their direction to advance their knowledge and experience.

The language used here is deliberate: ‘shall’ as opposed to ‘should’ implies an obligatory and not an optional obligation.

It is also worth pointing out that acting ethically also has a relevance to the *Fair Trading Act*, formerly the Commonwealth Trade Practices (Australian Government, 1974) laws, where the penultimate dot point above has relevance in all trade and commerce, specifically because misleading and deceptive behaviour, whether intentional or unintentional, is prohibited and can lead to prosecution of the manager and the organisation.

1.5.2 Effective leadership

AN EFFECTIVE LEADERSHIP ATMOSPHERE

Imagine a mining operation where the weekly induction of new site personnel is opened by the site general manager or by one of the department managers to introduce the organisation, the operation and ‘the way things are done around here’.

In the opening, the manager clearly explains to the inductees the operation’s core values, what will be expected of them while on the site, what they can expect to see in the operation, what they can expect from site leaders, and what the value proposition is for them beyond picking up their pay.

The manager then takes questions and answers them clearly, leaving the inductees in no doubt about what the site leadership stands for and what they expect. During the course of the induction the department managers have presentation slots or are introduced, as are the superintendents who will have inductees working in their areas. The site leadership team commits to this because they understand the importance of first impressions in setting the tone of a workplace and the importance of visual leadership.

Now let’s move past induction and into the workplace.

Housekeeping is of a high standard. The people who work there understand the required standards and take pride in their workplace. They keep it that way without having to be told to do so by their supervisors. People routinely act themselves on identified hazards, substandard conditions or risk-taking behaviour of others because they understand their duty of care and they take it seriously. People do not walk on by.

Senior site managers and superintendents are often seen in the workplace talking with people about how they are going about their work and how things can be done better and more safely.

People understand their place in the organisation, the impact of their work on business outcomes and on what they need to focus. There is acceptance that one is never as good as one can be.

People routinely raise opportunities for improvement because they want to build a better organisation and they know that their ideas are valued, will be given due consideration and that they will get timely feedback from their supervisor. They understand that a robust operation is the foundation of employment continuity and better conditions. They are proud to be part of the organisation.

People's career development is managed in a structured way with ongoing coaching, training and skills development. The organisation also provides tangible expressions of care in its ongoing commitment to the health and wellbeing of its people.

There is no interference from third parties. Site people trust and respect their leaders; they neither look for nor would tolerate anything to interrupt this direct relationship. At times they may not like some of the decisions taken by the site leaders but such decisions are always thoughtfully communicated and people understand that difficult decisions have to be made for the benefit of the operation.

Mine managers should consider whether their mining operations are similar to that described above; an example of effective leadership. There might otherwise be a great opportunity for improvement.

PRACTICAL REQUIREMENTS OF EFFECTIVE LEADERSHIP

What is leadership? It can be defined as influencing people to direct their discretionary effort to a common goal. Discretionary effort can be seen in two ways. One is simply how a person chooses to act when confronted with choices. The other is more telling of business leaders – it is how a person chooses to act when the opportunity arises to do something beyond the minimum work requirement. This is seen when people make choices for the benefit of the organisation because they see it as the right thing to do and are motivated to do so.

In the author's terms the group referred to as 'management' of a mining operation includes all those people accountable for the work outputs of others – from the senior site executive to the front line supervisor. This is the site leadership group, and all of these people are leaders in their own right. How effectively they exercise their leadership of others directly impacts the outcomes in all facets of the organisation.

There is competition in the mining industry for three things – access to capital, land and talent. All organisations essentially have access to the same technology and equipment but capable people are key to the success of a mining operation.

How does one attract, motivate and retain capable people? The 'hygiene factors', such as remuneration, rosters, camp accommodation and workplace facilities are generally industry competitive. The chief 'motivation factor', leadership, is the critical differentiator in the attraction and retention of talent at all levels of a mining operation. In the author's opinion this far outweighs anything else in causing people to want to be at work and to apply their discretionary efforts to the success of the organisation.

Effective leadership requires:

- visibility – getting out of the office
- setting direction and engaging openly with people to build agreement around how things will be done – ongoing clear and simple communication is critical

- setting an impeccable leadership example that models ‘the way we do things around here’
- recognising and positively re-enforcing desired behaviours and outcomes
- addressing poor behaviour and outcomes in a timely and positive way
- building great teams and developing people, especially through thoughtful coaching
- regularly reviewing, assessing and communicating how things are travelling.

Mining operations are generally conducted in a dynamic and complex environment. There is high reliance on people making the right decisions – using their discretion and contributing constructively. The degree to which this is achieved is a direct consequence of leadership.

Effective leadership requires courage, persistence and effort. The prize is definitely worth the hard work. It is a key differentiator between also-ran operations and great mines. In fact, it is often the reason that great assets change hands.

Mine managers must make a conscious decision to be effective leaders.

1.5.3 Building effective teams

There is no shortage of management theory on team building and how to build effective teams. In this section it is not proposed to summarise such a wide body of work – rather a summary is presented of what is possibly amongst the best known practical approaches, not only to optimal team building, but also to understanding individual and team behaviours.

Teams need to be assembled with care. This is because a team is not just a group of people with job titles, each of whom has a role understood by others in the team. What happens in practice is that team members tend to seek out certain roles and they perform most effectively in the ones that are most natural to them. As a consequence, if the input roles are unbalanced, or some are missing, the team is unlikely to produce quality output.

This observation was originally made by Professor R Meredith Belbin (1993), the originator of the well-known ‘9 Team Roles’. Belbin proposed that a balanced team should comprise team members who cover all or most of the nine team roles, whether as their primary or secondary behavioural style. The team roles are presented in Figure 1.5.1.

Most mine managers will readily recognise each of these team roles, reflected in the behaviours of those around them. But as Belbin observed, what is visible about them, the uniform they wear or the job they do may not be a true indicator. In addition, the role a manager may have for a person in a team (their assigned team role) may not be a match for the work (functional) role.

Pre-employment psychometric testing may also be of use in determining the potential team role of a new employee.

Referring back to Figure 1.5.1, the following dot points indicate where the nine team roles are most likely to be found in a mine site environment, though the examples are by no means exhaustive:

- plant – research department, mine planning, geology, assay lab
- resource investigator – marketing department, sales
- coordinator – mine manager, training department
- shaper – general manager, CEO, shift boss, foreman, nurse
- monitor evaluator – accounting, audit
- teamworker – human relations, public relations

FIG 1.5.1 - The nine Belbin team roles. Reproduced by kind permission of BELBIN Associates, United Kingdom (<http://www.belbin.com> – for all your individual, team and organisations team role behavioural needs).

- implementer – project manager
- completer – accounting, audit
- specialist – consultants, academics.

Once a manager is able to understand and recognise the team roles in the behaviours of the persons in the organisation, it becomes possible to assemble optimal teams for different assignments. It is also recommended that managers are always alert to potential team role gaps, as well as clashes and overlaps. Regrettably, the minerals industry, not to mention the wider world, seems too often to reach imperfect decisions as a result of suboptimal team building and predictably imperfect output.

Finally, having mastered these skills, it is also possible to utilise these tools when in a negotiating context, as the tools enable managers to ‘code’ their opponents and therefore devise the most successful behavioural counters. This may be an ideal example of the summation offered here: *different people for different teams, but always a balance of as many of the team roles as possible.*

The following section will deal with the board of directors.

1.6 THE BOARD OF DIRECTORS

In this section, various aspects of the roles and responsibilities of the board of directors is discussed, with some emphasis on the relationship between such boards and the executive management, be that on or off-site in the mining context.

1.6.1 Functions and responsibilities of the board

The role of the board is to provide leadership for and supervision of the organisation’s senior management. The board provides the strategic direction of the organisation and regularly measures the progression by senior management of that strategic direction.

The role of senior management, on the other hand, is to progress the strategic direction provided by the board. In particular, the chief executive officer, or equivalent, is responsible for the day-to-day activities of the organisation in advancing the strategic direction.

The functions and responsibilities of the board may be summarised as follows:

- overseeing the organisation, including its control and accountability systems
- appointing the chief executive officer, or equivalent, for a period and on terms as the directors see fit and, where appropriate, removing the chief executive officer, or equivalent
- ratifying the appointment and, where appropriate, the removal of senior executives, including the chief financial officer and the company secretary
- ensuring the organisation’s policy and procedure for selection and (re)appointment of directors is reviewed in accordance with the organisation’s nomination committee charter
- approving and monitoring compliance with the organisation’s diversity policy
- approving the organisation’s policies on risk oversight and management, internal compliance and control, code of conduct and legal compliance
- satisfying itself that senior management has developed and implemented a sound system of risk management and internal control in relation to financial reporting risks and reviewed the effectiveness of the operation of that system
- assessing the effectiveness of senior management’s implementation of systems for managing material business risk, including the making of additional enquiries and to request assurances regarding the management of material business risk, as appropriate
- monitoring, reviewing and challenging senior management’s performance and implementation of strategy
- ensuring appropriate resources are available to senior management
- approving and monitoring the progress of major capital expenditure, capital management and acquisitions and divestitures
- approving the annual budget of the organisation

- monitoring the financial performance of the organisation
- ensuring the integrity of the organisation's financial (with the assistance of the audit committee, if applicable) and other reporting through approval and monitoring
- providing overall corporate governance of the organisation, including conducting regular reviews of the balance of responsibilities within the organisation to ensure division of functions remain appropriate to the needs of the organisation
- appointing the external auditor (where applicable, based on recommendations of the audit committee) and the appointment of a new external auditor when any vacancy arises, provided that any appointment made by the board must be ratified by shareholders at the next annual general meeting of the organisation
- engaging with the organisation's external auditors and the audit committee (where there is a separate audit committee)
- monitoring compliance with all of the organisation's legal obligations, such as those obligations relating to the environment, native title, cultural heritage and occupational health and safety
- making regular assessment of whether each non-executive director is independent in accordance with the organisation's policy on assessing the independence of directors.

The board may not delegate its overall responsibility for the matters listed above. However, it may delegate to senior management the responsibility of the day-to-day activities in fulfilling the board's responsibility, provided those matters do not exceed what would otherwise be termed as 'material responsibilities'.

Senior management is responsible for supporting the managing director and to assist the managing director implement the running of the general operations and financial business of the organisation, in accordance with the delegated authority of the board. Senior management is responsible for reporting all matters that are potentially material at first instance to the managing director or, if the matter concerns the managing director, then directly to the chair or the lead independent director, as appropriate.

1.6.2 Corporate governance and due diligence

Corporate governance is a term used to describe 'proper arrangements' within a board. The Australian Stock Exchange (ASX) has prescribed ten principles that, taken as a whole, define corporate governance as follows:

- lay solid foundations for management and oversight
- structure the board to add value
- promote ethical and responsible decision-making
- safeguard integrity in financial reporting
- make timely and balanced disclosure
- respect the rights of shareholders
- recognise and manage risk
- encourage enhanced performance
- remunerate fairly and responsibly
- recognise the legitimate interests of stakeholders.

When used in this context, due diligence may be described by the extent to which the ten prescribed ASX principles of corporate governance are adhered to. The term is also used (in

another context) to describe a process of rigorous audit and examination of an operation, division or entire organisation, for the purposes of a merger, sale or acquisition.

1.6.3 Relationship with management

The board's relationship with the executive is usually via the managing director (or chief executive). The managing director is responsible for running the affairs of the organisation under delegated authority from the board and to implement the policies and strategy set by the board. In carrying out their responsibilities the managing director must report to the board in a timely manner on those matters included in the organisation's risk profile, all relevant operational matters and any other matter that is likely to have to fall within the 'materiality' concept.

All reports to the board must present a true and fair view of the organisation's financial condition and operational results. The managing director is also responsible for appointing and, where appropriate, removing senior executives, including the chief financial officer and the company secretary, with the approval of the board. The managing director is responsible for evaluating the performance of senior executives. Managing directors can (and frequently do) ask senior executives to attend board meetings to make presentations.

1.6.4 Site relationship with off-site management

It is natural that site mine management will communicate regularly with off-site management, within the same organisation, as proper corporate governance demands it. In most cases, where this occurs, the communication is between the mine site and a regional or head office. In addition, the communication will usually be between a decentralised centre and a major centre or city. Those who communicate from the mine site are usually the operations manager, mine manager, or other senior site management. Those at the other end either have a broader functional role (across more than one site) or are engaged in more corporate (as opposed to operational) responsibilities.

Communications with off-site personnel should therefore be managed with some care, and with due consideration to the following possible issues:

- differences in time zones
- potential for conflict between operational and corporate priorities
- the need to provide the operation-based information required off-site
- the need to promote support for operational requirements from off-site as needed
- the need to assist some off-site functions (such as marketing and external relations) as required
- the need to limit unauthorised or unwarranted off-site communication where it occurs.

In general terms, the mine manager should aim to have the support of the off-site general manager, in such a fashion as to not just report to him/her, but to be able to operate as a productive combination. The overall objective should ideally be that the general manager will represent the site as needed in the off-site context. It goes without saying, therefore, that this relationship is important to the healthy management of the site operation.

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CHAPTER 2

OCCUPATIONAL HEALTH AND SAFETY

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2.1 OCCUPATIONAL HEALTH AND SAFETY SHARED VALUES

2.1.1 Safety versus production

Historically, managing occupational health and safety (OH&S) was often seen simply as adding cost to mining operation. It was often said that doing things safely slowed things down, required extra equipment, and took extra people. This is in part due to the way that OH&S has traditionally been approached – as an afterthought, rather than an integral part of the design of a mining operation. Making a piece of equipment safe after it is purchased is always going to add to its cost.

Pressures on modern mines to be ever more productive, place many stressors on effective OH&S management. Issues such as the current skills shortage, the increasing technical sophistication of the industry, the need for specialist expertise and the reduction in conventional employment with the associated increased use of contractors create challenges in managing OH&S at mine sites (Gunningham, 2007, p 3). Gunningham also highlights the dualism of the industry, on one hand the consolidation of ownership of mine sites with a small number of major mining companies, and on the other hand the growth in small or very small enterprises operating in the industry. Small and medium size enterprises are less likely to understand legislative and management requirements, and less likely to have the skills or the willingness to take action and spend money on resolving outstanding OH&S issues (Gunningham, 2007, p 4).

The trend to longer work shifts has the potential to increase pressure on OH&S systems and increase risk of injury and illness. This is exacerbated by the increasing skills shortage and the associated need to cope with working longer hours. There have been many studies undertaken that highlight the link between absenteeism and accident rates at coal mines (Goodman and Garber, 1988). Job satisfaction is also a significant predictor of safety (Masai and Pienaar, 2011; Behm, 2009) and job insecurity and high turnover increases the likelihood of job risk behaviour (Emberland and Rundmo, 2010).

Modern safety management practices recognise that there is a close association between safety and reliability (Cox and Tait, 2002, p 1). It is suggested that there is a need for an integrated approach to safety, reliability and risk management:

This brings together efficient engineering systems and controls of plant and equipment (hardware), not only with efficient management systems and procedures (software) but also with a practical understanding of people (liveware) and a general knowledge of other human factor considerations (Cox and Tait, 2002, p vi).

In other words safety is linked to production and should not be dealt with in isolation. The same human factors that can affect safety also can affect production.

2.1.2 Promoting safe behaviours

There are four key elements to successfully promoting safe behaviour of workers:

1. management commitment and leadership
2. everybody accepting their responsibilities to work safely and not put the safety of others at risk (otherwise known as their duty of care)

3. involving and informing the workforce – generating ownership of safety
4. understanding that we are human and we will make mistakes.

Safe behaviour of workers at all levels in the organisation starts with the actions and leadership of those at the top. Australian Standard AS 4804:2001 outlines the general guidelines on principles, systems and supporting techniques for occupational health and safety management systems (OHSMS). The first step it outlines in establishing an effective OHSMS is setting out OH&S policy and objectives. It states:

To be effective, an OHSMS requires the participation and support from all parts of the organisation. Gaining this commitment from people requires senior management to demonstrate corporate commitment through leadership and the allocation of resources.

The standard goes on to outline the necessity of effective leadership and commitment in order to have an effective OHSMS. It outlines six key areas where effective leadership and commitment are required. These include 'management demonstrating their commitment by their own actions' and 'communication of the values and policies unambiguously throughout the organisation'.

The National Minerals Industry Excellence Awards for Safety and Health (MINEX) were until recently a key element of the Minerals Council of Australia's (MCA) safety and health leadership program, which aimed to eliminate industry fatalities, injuries and diseases. Since 1995, over 113 minerals industry operations have participated and a further 120 personnel have been involved as evaluators.

The MINEX process has assisted the Australian minerals industry to move closer to achieving its vision (Minerals Council of Australia, 2007). The elements are based upon the International Council on Mining and Metals' (ICMM) sustainability principles 4 – *Implements risk management strategies based upon valid data and sound science*, and 5 – *Seek continual improvement of our health and safety performance* (Minerals Council of Australia, 2005). Leadership at both site and corporate levels is recognised as being vital to good safety behaviour. Workforce involvement and communication also feature prominently in the assessment elements for the MINEX award.

Workforce involvement and ownership of safety is essential in generating a good safety culture at a mine site. Key to this is two-way communication between management and the workforce over safety issues and recognition by management of the pivotal role that the workforce has in managing safety. Adequate risk management can only be achieved with active involvement of the workforce in all phases of the risk management process.

Behaviour-based safety (BBS) (Institution of Occupational Safety and Health, 2006) focuses on improving the behaviour of the worker who could be involved in an accident. It attacks the human error behaviour of the worker with limited flow up the management chain to some at-risk behaviours of supervisors. The danger with BBS is the possibility of ignoring the factors beyond the control of the operator that can contribute to an accident. When talking about safe behaviour it is important to include the behaviour of individuals at all operating levels within an organisation. Appropriate behaviour at all levels is required in order for the safety culture to improve. StepChange (StepChange in Safety, 2007) developed a safety culture maturity model (SCMM) for safety improvement (Figure 2.1.1). Further details of the SCMM can be found in Fleming (2000). It is important to recognise what level of safety culture an organisation has in order to determine what behaviour modification programs are most appropriate and are most likely to be successful. Each level of the safety maturity model consists of ten elements:

FIG 2.1.1 - Safety culture maturity model (StepChange, 2007).

1. management commitment and visibility
2. trust
3. communication
4. participation
5. productivity versus safety
6. learning organisation
7. safety resources
8. shared perceptions about safety
9. industrial relations and job satisfaction
10. training.

Figure 2.1.1 has the stages of the model overlapping as it is quite possible for an organisation to have some elements slightly ahead or behind the others.

It is also important to understand human error or why people have accidents. Simpson, Horberry and Joy (2009) point out that error is an inherent part of being human. However, the potential for human error to create accidents can be controlled. They also debunk two 'myths' of human error:

1. human error effectively equates to front-line operator error
2. most human errors are caused by accident-prone people.

Simpson, Horberry and Joy (2009) go on to describe how errors can be classified in a number of ways. They combine the classification scheme of Reason with that of Rasmussen into:

- skill-based slips/lapses
- rule-based slips/lapses
- rule-based mistakes
- knowledge-based mistakes
- violations
 - routine violations – habitual behaviour that goes against the rules but seems to be the norm

- o situational violations – where factors within the workplace restrict or limit compliance with a rule
- o exceptional violations – where an individual is attempting to solve a problem and feels that violating a procedure is unavoidable
- o optimising violations – these emerge to make a work situation as interesting as possible because of boredom or inquisitiveness.

Reducing the level of error involves different strategies for each type of error. Too often we focus on training/retraining of the worker and ignore equipment design or working procedure design. In addition we may ignore the impact of the physical or psychological environment, for example production pressures or low visibility.

Simpson, Horberry and Joy (2009) demonstrate that there is a framework of influences of human error (Figure 2.1.2) based upon the work of Reason.

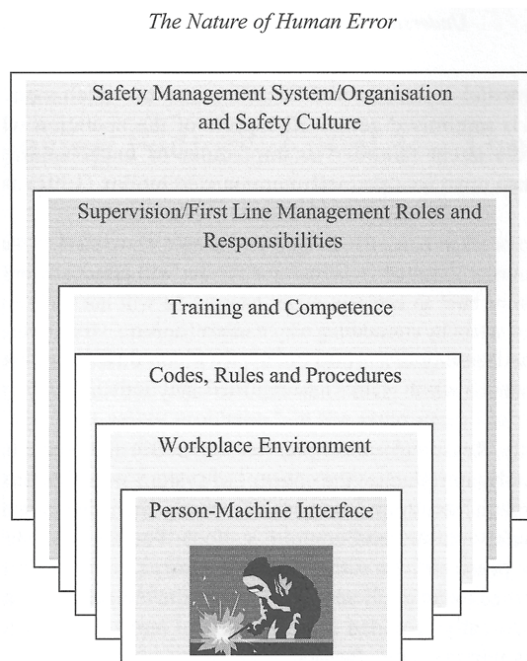


FIG 2.1.2 - Framework of human error influences (Simpson, Horberry and Joy, 2009).

Most errors are slips/lapses or mistakes with only 15 per cent typically being violations.

Another version of the Reason model was developed by Shappell, who pioneered the Human Factors Analysis and Classification System (HFACS). Recently his model was applied to the analysis of injuries in the Queensland mining industry (see Figure 2.1.3).

Analysis of over 500 incidents (see Table 2.1.1) indicated that in each case there was an operator error, but in about 25 per cent of cases there was inadequate supervision, in about 40 per cent of cases the physical environment contributed to the accident, over 30 per cent of instances were influenced by the technical environment and more than 25 per cent were affected by inadequate or ineffective communications.

2.1.3 The duty of care concept

At its heart duty of care is simply the obligation that everyone at a mine site has to work safely and not endanger the safety of anyone else. This obligation extends beyond the people

FIG 2.1.3 - Human Factors Analysis and Classification System model (Patterson and Shappell, 2009).

on a mine site and extends to those who supply services, equipment and products to the mine site. People who design and construct or import equipment, substances or services are also required to exercise their duty of care to provide the equipment or service not just fit for purpose but also in a way that does not put workers at an unacceptable level of risk.

Duty of care obligations extend to many persons, including:

- the holder of a mining lease
- the operator of a mine
- the senior site executive – site general manager
- a contractor
- a designer, manufacturer, importer or supplier of plant
- an erector or installer of plant

TABLE 2.1.1

Output from analysis of 508 incidents in the Queensland mining industry using the Human Factors Analysis and Classification System (source: Patterson and Shappell, 2009; reproduced with permission).

HFACS category	N (%)
Mining accidents (N = 508)	
Outside factors	
Regulatory influences	0 (0.0)
Other influences	0 (0.0)
Organisational influences	
Organisational climate	7 (1.4)
Organisational process	42 (8.3)
Resource management	5 (1.0)
Unsafe leadership	
Inadequate supervision	144 (28.3)
Planned inappropriate operations	60 (11.8)
Failed to correct known problems	20 (3.9)
Supervisory violations	7 (1.4)
Preconditions for unsafe acts	
Environmental conditions	
Technical environment	179 (35.2)
Physical environment	198 (39.0)
Conditions of the operator	
Adverse mental state	64 (12.6)
Adverse physiological state	32 (6.3)
Physical/mental limitations	55 (10.8)
Personnel factors	
Coordination and communication	138 (27.2)
Fitness for duty	2 (0.4)
Unsafe acts of the operator	
Routine disruption errors	299 (58.9)
Decision errors	249 (49.0)
Perceptual errors	25 (4.9)
Violations	28 (5.5)

- a manufacturer, importer or supplier of substances for use at a mine
- a person who supplies services to a mine
- the self-employed.

The level of responsibility included within this duty of care increases with the level of responsibility and authority at a mine site, ie those with the greatest ability to influence health and safety must exercise it. In common with main stream OH&S legislation the primary duty of care chain is via the employer. The primary duty of care lies with the

employer who must, as far as practicable, provide a work environment in which employees are not exposed to hazards and provide information, training and supervision.

For example, the *Queensland Coal Mining Safety and Health Act (CMSHA) 1999* outlines the obligations of the site senior executive to include the need:

- to ensure the risk to persons from coal mining operations is at an acceptable level
- to ensure the risks to persons from any plant or substance provided by the site senior executive for the performance of work by someone other than the site senior executive's coal mine workers is at an acceptable level
- to develop and implement a safety and health management system for the mine
- to develop, implement and maintain a management structure for the mine that helps ensure the safety and health of persons at the mine
- to train coal workers so that they are competent to perform their duties
- to provide for
 - adequate planning, organisation, leadership and control of coal mining operations
 - the carrying out of critical work at the mine that requires particular technical competencies
 - adequate supervision and control of coal mining operations on each shift at the mine
 - regular monitoring and assessment of the working environment, work procedures, equipment and installations at the mine
 - appropriate inspection of each workplace at the mine including, where necessary, preshift inspections.

Obviously the obligation is increased in situations where there is a potential for increased risk, such as where inexperienced workers are operating, or where the environment is more hazardous. Underlying the duty of care principle is the desire to encourage management of OH&S rather than compliance with regulation.

The CMSHA also details the duty of care responsibilities for designers, manufacturers, importers and suppliers of plant to ensure that:

- risk to persons from the use of the plant is at an acceptable level
- the plant undergoes appropriate levels of testing and examination to ensure compliance with the obligations
- all reasonable steps are taken to ensure that appropriate information about the safe use of the plant is available, including information about the maintenance necessary for safe use of the plant.

2.2 HEALTH AND SAFETY STRATEGY FORMULATION

2.2.1 Safety systems

Safety management systems are no different in concept to any other business management or quality management system. There are two Australian standards explicitly dealing with occupational health and safety management systems:

1. AS/NZS 4801:2001 Occupational health and safety management systems – specification with guidance for use

2. AS/NZS 4804:2001 Occupational health and safety management systems – general guidelines on principles, systems and supporting techniques.

AS 4801:2001 defines an occupational health and safety management system (OHSMS) as part of the overall management system, which includes organisational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the OH&S policy, and so managing the OH&S risks associated with the business of the organisation.

AS 4801:2001 outlines the specification with guidance for use and sets out the audit framework.

AS 4804:2001 outlines general guidelines on principles, systems and supporting techniques:

- how to set up an OHSMS
- how to continually improve an OHSMS
- resources required to set up and continually improve an OHSMS.

Like a number of Australian Standards dealing with management systems AS/NZS 4804:2001 bears a remarkable resemblance to the quality management systems standard described in ISO 9001. Indeed change a few words here and there and it is the same.

AS 4804 is not the only way to design and implement an OHSMS; it is one way based on the ISO9000 QA systems approach similar to the AS/ISO 14001 Environmental Standard.

COMMITMENT AND POLICY

The first element for an effective OHSMS is commitment by management. This starts with a clear policy enunciating the commitment from the top to safety and health. It is vital to ensure that all levels are committed to this policy. It is a challenge to ensure that leadership demonstrates clear commitment and support for safety and does not send out mixed messages – production and safety.

This concern over communications and commitment is also being reflected in the review commissioned by the New South Wales Mine Safety Advisory Council. A discussion paper presented by Neil Gunningham at the 2007 Occupational Health and Safety Regulations Research Colloquium in Canberra discusses the disconnect.

PLANNING

Planning requires:

- systems for identification of hazards, hazard/risk assessment and control of hazard/risks
- compliance with relevant legislation and other requirements
- the clear statement of objectives and targets
- identification of performance indicators and how to measure/assess them
- the development of OH&S management plans.

IMPLEMENTATION

At the implementation phase it is imperative to ensure capability to:

- integrate with existing management systems
- identify accountabilities and responsibilities

- consult with all stakeholders, motivate and make aware
- provide adequate training and competency of all personnel as appropriate to their level of involvement in the system
- supply goods and services to ensure effective implementation.

Implementation of the OHSMS must be supported by:

- effective communication to all stakeholders
- effective reporting of progress and difficulties
- documentation (a balance between too little and too much)
- control of documentation (it tends to breed in the dark)
- record keeping and information management.

Hazard identification assessment and control should include:

- hazard identification
- hazard/risk assessment
- control of hazard/risk
- design, fabrication, installation and commissioning of control systems
- administrative control
- purchasing.

Another facet of implementation is the preparedness for things to go wrong. Contingency preparedness and response should include:

- emergency or disaster management plans
- capability to respond to incidents involving workers
- critical incident recovery plans covering
 - defuse – prevention of emotional escalation
 - debrief – information collection on incident from personnel
 - counsel – comfort/support distressed persons
 - legal issues – prepare for any legal proceedings.

MEASUREMENT AND EVALUATION

A key feature in the effective implementation of an OHSMS is the monitoring of the performance of the system against objectives – both process and outcomes.

Measurement includes:

- measure, monitor and evaluate the OH&S performance and take corrective action
- inspection, testing and monitoring elements of an OHSMS
- audit of the OHSMS
- corrective and preventive action including accident investigation.

REVIEW AND IMPROVEMENT

The final element of the OHSMS is the review and improvement phase, which then feeds back to the beginning, causing a revision of the earlier elements as required to meet the desired outcomes. It is important to enshrine an effective review and improvement process in the system, based not only on regular reviews but also triggered by changes in circumstances or significant events.

LEGISLATIVE REQUIREMENTS FOR OCCUPATIONAL HEALTH AND SAFETY MANAGEMENT SYSTEMS

The various state legislations have differing requirements or specifications for OHSMS. These range from no explicit requirement in Western Australia to safety case for major hazardous facilities in Victoria. The harmonisation of state occupational health and safety legislation and the National Mine Safety Framework will lead to a much more consistent legislative approach, requiring the implementation of an OHSMS at mine sites except in some special circumstances, such as for small operators and gemfields.

New South Wales Guidance Note GNC-003, *Preparing a health and safety management system* (New South Wales Department of Primary Industries, 2007), provides guidance to operators of coal operations regarding the duty to prepare a health and safety management system for a coal operation. An OHSMS is required under section 20 of the *Coal Miner Safety and Health Act 2002* (CMSH). An overview of the contents of an OHSMS under New South Wales legislation is given in Figure 2.2.1, extracted from the guidance note. It is important to note that Clause 14 of the CMSH Act states that the health and safety management process must be consistent with AS 4804 (see Figure 2.2.2).

The Queensland legislation provides less detailed guidance on OHSMS, but is consistent with AS 4804.

FIG 2.2.1 - Occupational health and safety management system contents.

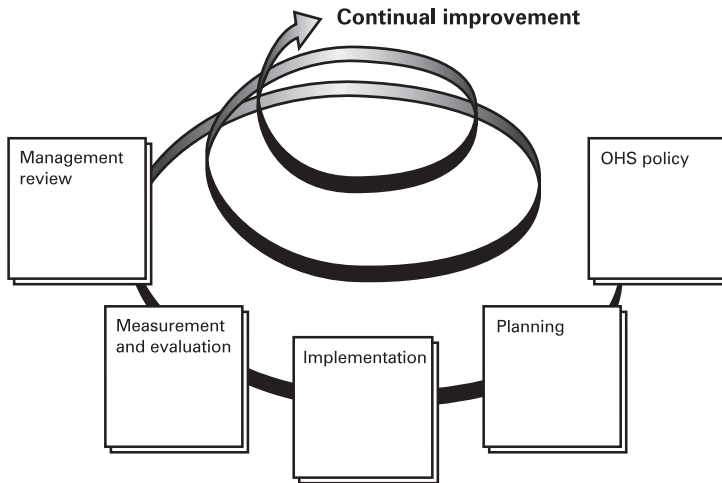


FIG 2.2.2 - Occupational health and safety management system as per AS 4804.1.¹

2.2.2 Communicating the message and culture

Key to the successful implementation of an OHSMS is total management commitment – not just an OH&S policy document framed and on the wall of the office, but a personal commitment by each member of the management team to OH&S. Having a policy is a start, but communicating it and getting it accepted is a much more complex process. It involves accepting all the principles outlined above as emphasised in the following list:

- Safety is first, there can be no production versus safety arguments. Too often the priority of safety is undermined by unconscious and unintended behaviour. For example, having the production output display as the last thing the workers see before they go underground indicates what the most important thing to management is.
- Do as I do, not as I say. Cultural violations are those caused because it is accepted that rules can be broken – taking shortcuts for example. It is also important not to have rules that are impractical or in themselves can be dangerous.
- Management must fully support and not penalise workers who stop work or refuse to undertake activities that are unsafe.
- Encourage innovation and worker involvement in improving safety. Simply having quotas on job safety analysis means that people carry them out, not that they are done properly.
- Be careful how safety performance indicators are used and in the use of any rewards for meeting targets. If you are not careful, meeting the target becomes more important than working safely. Often process indicators are better at indicating how well plans or processes are being implemented. Further details on the pitfalls of safety incentive schemes can be found in the report by the Mines Occupational Safety and Health Advisory Board (1999) and the New South Wales Minerals Council (1998) report.

The safety culture maturity model outlined above can help in the selection of the appropriate ways to implement and operate an OHSMS. It also allows the selection of

1. AS 4804.1 Figure 1 (Preface) – reproduced with permission from SAI Global Ltd under Licence 1209-c003. AS 4804.1 is available for purchase via <http://www.saiglobal.com>

appropriate performance measures relative to where the mine site is on the safety culture maturity ladder. Table 2.2.1 demonstrates the way performance indicators can change depending on the level of safety culture maturity.

TABLE 2.2.1
Examples of leading indicators of safety performance (StepChange).

Level 1	Level 2	Level 3
Has a safety policy been published?	Has the safety policy been adequately communicated?	% of staff with agreed occupational health and safety management system responsibilities and accountabilities
% of legislation addressed by company procedures	Perceptions of management commitment to safety	% of planned training courses completed
% of statutory training completed	Number and effectiveness of senior managers safety tours	% of identified competency gaps addressed
Extent of communications of statutory requirements to employees	Extent to which plans and objectives have been set and achieved.	% of equipment safety tests meeting performance criteria
Number of training hours	% planned safety training completed	Number of critical drawings awaiting updating
% of management and supervisor job descriptions that contain specific health and safety responsibilities	No. of risk assessments updated as a result of changes in work scope	Number of safety improvement actions per inspection
% of safety management system	% of manual handling assessments completed	% of jobs for which risk assessment has been carried out
Number of completed monitor/audit/review activities versus number planned	Extent of compliance with risk control measures	% of reduction in exposure to hazardous activities
Number of management safety visits versus number planned	Number of suggestions for safety improvement	% of worksite inspections carried out against planned requirements
Trend of non-compliance note from working practices	Number of safety audits planned and completed	% of jobs with hazard assessments
	Safety audit recommendations closed out on time	% of permits to work reviewed and controls found to meet requirements
	Time to implement action on complaints or suggestions	
	Frequency and effectiveness of safety briefings	
	Number of additional control measures identified at site during execution of work	

There are many publications outlining performance indicators including those by StepChange in Safety (2005) the Minerals Council of Australia (2001) guide and the Australian Safety and Compensation Council (2005) guide to positive performance indicators.

2.2.3 Hazard identification

For an OHMS to operate effectively it is essential to have an understanding of the biological, psychological and social aspects of the individual and in some cases the group and the

hazards to which they may be exposed in the work environment. Whilst specialists can be consulted with regard to the human issues, it is essential that managers, designers and their technical advisors develop an appreciation and understanding of the potential hazards and consequences as well as methods of their control.

One method of assessment is the energy damage criteria outlined in Tables 2.2.2 and 2.2.3, a concept used in many industries and which follows issues identified in the 2010 Safety Institute of Australia 'Body of Knowledge' project. Tables 2.2.2 and 2.2.3 outline the categories and then industry-related examples using the energy damage criteria.

TABLE 2.2.2
Categories of damaging energy.

1. Human energy	6. Electrical energy	11. Other energy
2. Gravitational energy	7. Thermal energy	12. Susceptible part
3. Vehicular energy	8. Chemical energy	13. Specialised shape
4. Machine energy	9. Radiation energy	14. Insufficient information
5. Object energy	10. Noise energy	15. Disasters (potential/multiple fatalities)

The energy damage criteria is one of many similar criteria that can be employed to effectively understand how injury and/or health effects occur and is required to be able to identify hazards and to act proactively to prevent future incidents. The energy damage criteria are particularly simple to understand by scientists and engineers as the concept is central to their understanding of the world in which they operate. In the Australian Standards framework 'hazard' is defined as the source of potential harm and 'risk' is the chance or probability that a person(s), equipment or the environment is harmed or damaged if exposed to the hazard.

As well as the damaging energies listed in Table 2.2.2 the category of other energies includes biological energy, biochemical energy, animal energy, atmospheric pressure energy and pressure energy. As such the method is very flexible and each of the energies can be added to and subdivided as required.

LIMITATIONS OF THE ENERGY-DAMAGE CONCEPTION OF HAZARD

The limitations of the energy-damage conception of hazard are summarised by the Safety Institute of Australia (2012) as follows.

Situations with a high human-factor component

The concept of hazards as potentially damaging energy is not helpful when the expression of damage is affected by human-factor components, such as in biomechanical or manual-task-related hazards and psychosocial hazards. The expression of biomechanical hazards may be determined by human factors such as age, gender, fitness, anthropometry and technique. The expression of psychosocial hazards may be affected by factors such as self-esteem, competence and coping mechanisms. While in modern OH&S practice these types of factors are unlikely to be the focus of primary control strategies, it is likely that in the future these types of factors will be the focus of secondary control strategies for psychosocial hazards.

This reinforces the importance of understanding the complex interactions of these factors in the expression of the hazard.

TABLE 2.2.3

Schedule detailing examples of hazards based on damaging energy criteria.

Damaging energy category		Damaging energy mechanism	Examples of hazards (the potential for harm)
Activity: underground mining and exploration			
Access to workplace	Human energy	Lifting, carrying, slip/trip, impact body part.	Hitting head, uneven ground.
	Gravitational energy	Falling: same level, from height. Falling objects.	Rockfall, falling from ladder.
	Vehicular energy	Single vehicle accident, collision with other vehicle or pedestrian, vibration/jolt on uneven ground.	Hit by vehicle, collision when in vehicle.
	Thermal energy	Prolonged exposure to hot/cold environments.	Recirculating ventilation, high humidity with high temperature.
	Chemical/radiation energy	Damage from inhalation or absorption and contact effects. Oxygen deprivation.	Entering old workings (unventilated), radon daughters.
Channel sampling and geological mapping	Human energy	Overexertion, awkward or repetitive work.	Heavy lifting.
	Gravitational energy	Fall of ground.	Rockfall from roof or sidewall.
	Object energy	Impact/crushed by object.	Struck by hammer/flailing hose.
	Machine energy	Direct contact with moving parts of hand-held/portable tools.	Sleeve caught in rotating power tool.
	Electrical energy	Contact with electrical power cables.	Penetrate electrical cable with tools, faulty electrical equipment.
	Noise energy	Exposure to noise.	Working adjacent to ventilation fan or active equipment (drill).
	Susceptible parts	Low velocity objects (failure to wear personal protective equipment).	Dust or foreign object in eye. Skin damage from abrasion, lung damage from inhalation of smoke/dust/vapour.
Other potential underground mining hazards	Disasters	Explosions.	Unplanned initiation of explosives, unauthorised entry to blasting zone.
		Structural collapse.	Pillar failure, gas outburst, seismic event.
		Fires.	Vehicle fire.
		Flood/inrush.	Accessing old workings. Surface inundation from river/tailings dam.
		Toxic atmospheres.	Entering recently blasted area. Smoke from tyres on fire.
		Lost/trapped.	Working alone, no communications, fall of ground, gas outburst, fire, no alternative egress.

TABLE 2.2.3 CONT...

Damaging energy category		Damaging energy mechanism	Examples of hazards (the potential for harm)
Activity: surface mining and exploration			
Access to workplace	Human energy	Lifting, carrying, slip/trip, impact body part with object. Cumulative damage through awkward or sustained work postures or repetitive work.	Carrying/moving/pushing/pulling/lifting heavy loads. Overstressing body-parts. Uneven ground, swamps, hill climbs.
	Gravitational energy	Falling: same level or from height. Falling or toppling objects.	Concealed shafts. Working under highwall or bench, climbing rock face. Tyre change.
	Vehicular energy	Single vehicle accident, collision with other vehicle or pedestrian or animals, vibration/jolt on uneven ground. In vehicle during collision/rollover.	Hit by vehicle. Too fast on dirt roads. Excessive speed. Inattention. Excessive driving periods. Driving when tired.
	Object energy	Impact/trapped/crushed by object. Projectiles.	Falling tree, swinging crane load, hammer blow. Hunters (firearms).
	Machine energy	Direct contact with moving parts of plant.	Replacing vehicle fan belt.
	Thermal energy	Prolonged exposure to hot/cold environments.	High humidity with high temperature. Camping in inclement weather.
	Chemical energy	Damage from inhalation or absorption and contact effects. Oxygen deprivation.	Entering cave, adit. Sampling asbestiform or siliceous minerals.
	Radiation energy	Exposure to natural or instrument-generated UV radiation.	Sunburn. Eye damage.
	Noise energy	Damage from excessive sound pressure of varying intensities and exposure.	Continuous or medium to high intensity exposure to radio, MP3 players or machine noise.
Core shed/ exploration/ geological mapping	Human energy	Lifting, carrying, slip/trip, impact body part with object. Cumulative damage through awkward or sustained work postures or repetitive work.	Carrying/moving/pushing/pulling/lifting heavy loads/ rods. Overstressing body-parts. Uneven/unstable/ overgrown ground or diggings.
	Gravitational energy	Slips and falls rearwards, or rolled ankle from rough ground or stepping on edge. Falls while ascending/ descending. Falls from +2.1 m. Impacted by falling object.	Working in and around stacked core boxes. Traversing broken rock/scree. Running (drill) rods. Poor lighting. Wet ground/wet rocks.
	Vehicular energy	Damage caused by vehicle.	Vehicle collides with pedestrian, eg forklift. Rolled vehicle, crushing when vehicle on jack collapses.
	Object energy	Impact/trapped or crushed by object. Imparted pressure energy, imparted tension/compression.	Hydraulic hose failure. Pressure vessels exposed to heat. Vegetation clearing (axe, machete).
	Machine energy	Direct contact with moving parts of hand-held/portable tools/drill.	Loose sleeves using rotating power tool. Vibration on drill deck, using chainsaw. Core cutting saws.
	Electrical energy	Contact with electrical power cables.	Penetrate electrical cable with tools. Unearthed electrical tools.

TABLE 2.2.3 CONT...

Damaging energy category		Damaging energy mechanism	Examples of hazards (the potential for harm)
Activity: surface mining and exploration			
Core shed/ exploration/ geological mapping	Thermal energy	Contact with hot/cold objects. Exposure to environmental heat/cold.	Metal exposed to sun. Unprotected exposure to sun, wind, cold.
	Chemical energy	Damage from inhalation, absorption or contact	Drilling, sample preparation or analysis.
	Noise energy	Continuous exposure.	Exploration drilling equipment.
	Susceptible parts	Low velocity objects (failure to wear personal protective equipment).	Dust or foreign object in eye. Exposed skin. Lung damage from inhalation of smoke/dust/vapour.
	Animal/biological energy	Damage from interaction with animals and insects or disease.	Wildlife, including bats, snakes, mosquitoes, parasites, ticks, leaches. Wading or swimming in freshwater rivers, ponds. Ross River fever, typhoid, bilharzia.
Other potential surface mining hazards	Disasters	Explosions.	Geoseismic field work.
		Fires.	Bush fire, vehicle fire. Accommodation, eg hotels, places of entertainment.
		Flood.	Fast rising/flowing river to cross. Deep ford/river crossing.
		Toxic atmospheres.	Smoke from bushfire, confined space.
		Storm or tempest.	Cyclone, high winds, blocked progress (fallen tree, swollen river).
		Firearms (accidental discharge).	Carrying firearms (for personal protection against wild animals, eg wild boars). Hunters.
		Aircraft accident.	Adverse weather for helicopter/light aircraft. Inadequately prepared helicopter landing pads.
		Environmental.	Transporting hazardous substances.
Activity: office and administration (including field activities)			
Office/ administration	Human energy	Heavy lifting, pushing, pulling, or carrying requiring strong effort. Impact body with object, repetitive work.	Poor ergonomics, cluttered workstation. Poor illumination, insufficient area to work.
	Gravitational energy	Fall (slip or trip) of person on level or ascending/descending ground.	Leaning back or faulty chair. Stairs. Tripping on poorly secured power cords. Falling off ladders.
	Machine energy	Contact with moving parts.	Paper jam in copying machine or printer.
	Object energy	Machine energy imparted, pressure energy imparted, or tension/compression imparted.	Stapler, guillotine, scissors, slamming door.

TABLE 2.2.3 CONT...

Damaging energy category		Damaging energy mechanism	Examples of hazards (the potential for harm)
Activity: office and administration (including field activities)			
Office/ administration	Electrical energy	Contact via portable extensions or appliances (tools). Contact via power or lighting circuits.	Power leads, changing light bulbs or fuses, exposure to live wires or contacts.
	Chemical energy	Inhalation, contact, ingestion, injection or absorption.	Stored hazardous substance, smoking.
	Biological/ biochemical/ animal energy	Biological or biochemical activity from airborne, ingested or animal source.	Food stored too long, air conditioning (Legionnaire's disease). Poor housekeeping. Poor sanitation. Undercooked meat and food. Spiders, snakes.
	Susceptible parts	Damage to eyes, skin, lungs or other major organs.	Working under stress, sleep deprivation, drugs or alcohol. Exposure to chemicals.
	Disasters	Fire/explosions.	Temporary camp, use of paraffin lamps, gas bottles, campfire cooking.
		Large structural collapse/cave in (subsidence) or landslide.	Offices/camp adjacent to mining operations.
		Flood/cyclone.	Limited outside communications/ weather forecasts.
		Management/contractor failure.	No management system in place. Little quality control/documentation or back-up systems.

Source: *Field Geologists' Manual*, fifth edition (The Australasian Institute of Mining and Metallurgy: Melbourne).

Hazards where effects have a long latency period

There are occasions when damage or ill health is manifested and investigators of OH&S problems must retrospectively determine the hazard(s) that was the source(s) of the effect(s). During a long latency period (eg it is not uncommon for asbestos exposure to result in disease 40 years post-exposure), various work and personal circumstances can influence the outcome of the harm, making detection of the specific hazard(s) difficult. In such situations, simplistic definitions of hazards and the energy-damage definition are of limited value.

Multiple hazards

In cases where the type of risk (ie the possible injury or harm to health) stems largely or entirely from *one* type of hazard, the issues surrounding terminology might not be problematic. However, harm may result from the interaction of several hazards, such as the synergistic effect of psychosocial and biomechanical hazards and ototoxic chemicals that, in combination with noise, have a more detrimental effect on hearing than noise alone. In such cases, the 'damaging energies' concept may result in risks being controlled independently of each other.

Hazards arising from complexity

Recent research and discussions focus on OH&S as part of complex systems. From such a perspective, the OH&S professional must consider the functioning of the whole organisational system and comprehend how different elements and processes act together when exposed to a range of influences simultaneously, rather than just search for broken parts (Dekker, 2011, p 127). Traditional OH&S models are based on the premise that for incidents to happen, something or someone must break or malfunction. However, many writers (Dekker and others) have described a phenomenon of ‘drift’, where organisations fail because they normalise very small changes to parameters until the system as a whole drifts into an unsafe state. In complex systems, drift into failure can happen without anything breaking, or without anybody actively erring or violating rules. Fundamentally, this challenges assumptions about cause and effect. These processes are not particularly well understood as the growth of complexity in society and organisations has outpaced our understanding of how complex systems work and fail (Dekker, 2011, p xiii). In light of these observations, definitions of hazards may need reconceptualising and further revision as our understanding develops.

2.3 SAFETY STRUCTURE

2.3.1 Organisation

While safety is a key part of every person’s role at a mine site, it is important to understand how safety is formally integrated into the organisational structure and specific role responsibilities.

It will be important in considering the ‘organisation of safety’ in the operation to distinguish between each and every person’s responsibility for the health and safety of themselves and others, and the particular accountability for developing, implementing and maintaining the different aspects of the mine’s OHSMS. The organisational structure and roles should be integrated with, and support, the mine’s OHSMS.

At a high level, three alternatives exist for structuring the management of safety systems within the organisation. A summary of these alternatives is given below, in order of increasing cultural maturity.

SAFETY SUPERVISION DEPARTMENT

Under this structure, a separate safety department is established in the organisational structure. This department is responsible for developing the safety systems and safety rules for the entire workforce. The department is also responsible for enforcing these rules and systems. Members of the department, which sits in a self-contained part of the organisation, will perform inspections and audits of workplaces, and act on their findings either directly to the workers involved, or back via the management structure of the relevant department. Operational departments are effectively not responsible or accountable for health and safety in their area, but instead rely on the separate department to ensure safe processes and behaviours.

The advantages of this structure are that it places a significant emphasis on health and safety by the creation of a department specifically focused on these issues across the entire operation. The department is given authority to inspect all workplaces, and may have specific representatives working within the operational departments performing continuous inspections and enforcement.

The disadvantage of the structure is that health and safety is not included in the responsibilities of every role on site – it is effectively offloaded to the health and safety department. This reinforces an immature culture where safety is seen as someone else's task to enforce, rather than being owned by each and every person. Tension may also be created between the potentially conflicting interests of the safety department, and those of the operational departments.

Safety must be integrated as a key part of every function and role, it cannot be an area that 'someone else' will worry about.

SUPPORTING A SEPARATE DEPARTMENT

The second alternative organisational structure is the most common in modern mining operations. Under this structure, a separate health and safety department is created, but its responsibilities do not extend to enforcement of safety rules and requirements. The department is responsible for bringing a specialist body of knowledge to the operation, for facilitating the development of the components of the OHSMS, and for providing support and training to the operational areas to assist them in managing safety in their departments. The health and safety department is not responsible for the safety performance of any department (except their own); they are primarily tasked with assisting the entire organisation to meet its safety objectives. Each individual operational department and team is accountable for their own safety performance.

For this structure to be successful, its purpose and scope of work of the safety department must be clearly defined. The people within the department must work proactively with the other departments to ensure their work is correctly focused on supporting the needs of the entire mine.

The advantages of this structure are that while the responsibility for safety is distributed throughout the entire organisation, a specialist department has the resources required for ongoing administration of the safety systems, and ensuring continuous improvement.

A disadvantage of this structure is that it is common for the safety department to become overwhelmed with the administrative components of their role, removing focus from their work in developing safety systems and continually improving the tools available for managing health and safety performance. The safety department may become a dumping ground for any administrative or non-core work even slightly related to safety that the operational teams do not wish to perform.

A key part of developing an effective safety culture is for leaders throughout the organisation to demonstrate that they consider safety an integral part of their role.

INTEGRATED ACCOUNTABILITY

The most mature model, but not necessarily the most effective, is for there to be no separate health and safety department at all. Rather, each operational department is responsible for managing all aspects of health and safety, from systems development to training to auditing and enforcement. Under this model safety management becomes an integral part of every role and every function, significantly enhancing safety culture.

The advantages of this model are that safety is owned by everyone throughout the organisation, and safety systems are developed by those who must implement them. Leadership and ownership are highly enhanced.

Several disadvantages exist, however:

- very strong management is required to ensure that safety is actually given sufficient time and effort by the operational departments, and that it is truly integrated into the organisation
- safety systems and management techniques may not be standardised across the operation, creating additional work and complexity and potentially eroding the confidence of the workforce
- without designated resources on site to focus on identifying leading practices and facilitating continuous improvement, the organisation may miss opportunities to improve
- the lack of a specialist, tertiary-qualified OH&S knowledge on site is a large gap in the organisational capability
- without the administrative functions of a safety department, resources and time are taken away from operational roles to perform tasks that should practically be given to a designated administrative function.

Finally, a key risk exists with this model that individuals will not prioritise their health and safety responsibilities as highly as they should, leaving the organisation weakened in this critical area.

2.4 SAFETY PROCESSES

2.4.1 Standards, policies and procedures

A mine's OHSMS is essentially a framework of documents, written at different levels of specificity and prescription, which when combined describe how safety and health will be managed in all areas and aspects of the operation. Three main types of documents in the system are standards, policies and procedures.

Standards are the highest level documents in this series, and typically contain overriding objectives and non-negotiable ways of operating the mine. Standards are literally that – the standards by which the mine will be run. Standards may also be referred to as management plans.

Policies describe the outcomes required in particular areas. For example a mine may have a drug and alcohol policy or a jewellery policy. Policy documents are usually used in areas where specific outcomes are required, and where there are a range of do's and don'ts that must be specified.

Policies define what outcomes the organisation wishes to achieve; procedures describe *how* to achieve these objectives.

Procedures contain the highest level of detail, and in most cases are written in a step-by-step format for people to follow to achieve certain objectives or complete certain tasks. Procedures may describe ways of working, ways of setting up certain areas of the mine, or ways of facilitating certain processes.

2.4.2 Risk assessment and management

Risk management is a systematic methodology for assessing those factors (both within and external to the organisation) that make it uncertain whether the organisation's objectives will

be achieved. These objectives may be related to production, standards, safety, financial, or any other area of performance. Risk management is the process for identifying the ways in which these objectives may not be achieved, and the effect this uncertainty has on the organisation.

The goal of risk management is to understand these uncertainties and risks, and find ways to reduce the likelihood of them occurring, or the impact they might have on individuals or the organisation.

As stated in ISO31000:2009 (Standards Australia, 2009):

All activities of an organisation involve risk. Organisations manage risk by anticipating, understanding and deciding whether to modify it. Throughout this process they communicate and consult with stakeholders, and monitor and review the risk and the controls that are modifying the risk.

The relevant standard for risk management is ISO31000, which has superseded the previous Australian Standard AS/NZS 4360. ISO31000 contains an overview of the risk management process, and practical methods for applying risk management techniques. These are summarised in the framework shown in Figure 2.4.1. All risk management activities on site should be carried out in alignment with ISO31000, and performed by persons competent in risk management generally, and trained in facilitating the specific risk assessment methodology to be used.

FIG 2.4.1 - Risk management framework as per ISO31000:2009².

2. AS/NZS ISO 31000:2009 Figure 1 (modified) – reproduced with permission from SAI Global Ltd under Licence 1208-c027. AS/NZS ISO 31000:2009 is available for purchase via <http://www.saiglobal.com>

A variety of methods and tools are available to facilitate effective risk management, and in particular for use in the risk assessment and risk analysis phases. These range from basic hazard identification (HazID), through the highly complex methods, such as hazard and operability studies (HAZOP) and semi-quantitative risk assessment (SQRA).

Health and safety legislation will also contain sections related to risk management, and may include specific requirements for the risk management processes to be followed, when risk assessment activities are to be performed and how risk management should be implemented and documented on site. All personnel on site should be trained to at least a basic level of understanding of risk management concepts and practices.

Several industry documents exist that may be used as reference guides for developing risk management systems:

- Department of Natural Resources and Mines Queensland, Recognised Standard 02 – Control of risk management practices, July 2003
- New South Wales Department of Trade and Investment, Mine design guideline MDG1010 – Guideline for minerals industry safety and health risk management, updated July 2011
- New South Wales Department of Primary Industries, Mine design guideline MDG1014 – Guide to reviewing a risk assessment of mine equipment and operations, July 1997.

2.4.3 Policy support and reinforcement

Health and safety policies must be embedded within the organisation, and reinforced through a number of channels in order to be effective. While the overarching policy may be a statement of the organisation's objectives for health and safety, it is often written in summary and directional language. This policy statement must be interpreted and communicated to the workforce in a range of ways.

The first exposure most employees and contractors will have to the mine's health and safety policy and management system is via their induction. The induction must include a clear statement of the policy, and an explanation of what this means for each and every person's role on site.

The policy and other standards should also be communicated through written and visual mediums across the site, and via campaigns from time-to-time focusing on specific aspects of health and safety systems or performance.

The most important way in which health and safety systems, standards and policies are reinforced is through the behaviour of leaders on site. More than anything that is written in documents or stated verbally, it is the actions of the leadership team on site that will have the most impact on health and safety performance. Leaders should be given training and models to follow to ensure they are demonstrating their safety commitment through their behaviours.

Each document (including standards, policies, procedures and management plans) in the OHSMS will contain a section detailing the roles and responsibilities defined in that document. It is critical that all persons are aware of their responsibilities as stated in each and every document in the OHSMS. A useful tool for achieving this is to create a single reference list that groups the responsibilities from all the management system documents into one place, sorted by role title. This reference list then forms part of the training and induction for each person on the mine site – allowing them to understand and signoff on all the responsibilities and accountabilities of their role. This list can also include responsibilities under external documents, such as legislation.

2.4.4 Follow-through and feedback

Safety messages and policies must be continually promoted and reinforced in order to retain their importance. It is also necessary to change the exact message and its mode of delivery regularly in order to ensure people continue to notice and act on the message.

A key aspect of maintaining this focus and ongoing communications is to ensure that any safety issue that is raised is acted on appropriately. Safety issues and hazards may be raised by members of the workforce, by external parties, or as the result of incidents or near misses.

Whatever the rectification action that is taken (or not taken) in response to these issues and hazards, the most important factor in developing a strong safety culture is the actions and feedback that comes from the leadership at the mine.

The management team of every department must ensure that they provide timely and honest feedback to the person that raised the issue. This feedback should include the findings of any investigation, the actions that are to be taken and the reasoning behind these decisions. During this feedback process, an opportunity is provided for the person to suggest any further actions that might be considered.

When people receive this feedback on the issues that they have raised, they feel encouraged to raise more issues in a proactive manner, and also feel that their opinion is valued by management. This in turn encourages people to take more responsibility for their own and others' safety, and to be more proactive in rectifying and/or reporting safety issues.

2.5 CURRENT ISSUES

2.5.1 Needs analysis

The first (and arguably most critical) phase in developing any system is to assess the needs of the organisation in relation to that system. This remains true whether the system is related to health and safety, training, asset management, human resources, or any other organisational function.

A needs analysis is undertaken to determine what functionality is required of a particular system. A needs analysis commonly includes two phases. The first is a document review and audit of the relevant external documentation, legislation and standards. The second phase is a consultation and/or interview process with the relevant members of the workforce and stakeholders. Between these two investigations a sufficient list of 'needs' or desired outcomes should be assembled.

The system or procedure can then be developed with these needs and outcomes in mind from the very start.

One of the most common forms of needs analysis performed on a mining site is a training needs analysis. A training needs analysis is performed on a particular role in the organisational structure. The role is assessed to determine what training and authorisations are required to competently perform the duties and obligations of that role. The needs identified are then listed in the training matrix as either mandatory or optional requirements. The process for conducting training needs analysis will include a review of the relevant OHSMS documents and legislation, consultation with industry best practice and a risk assessment.

2.5.2 Training records

The mine should keep records of the training, competencies and qualifications of all persons who are performing work on site. In the case of contractors, these records may be retained by the contracting company, so long as the mine is able to access them as required for verification and auditing.

Training records are maintained in a database, usually electronically. Hard copies of the completed training assessments and authorisations should also be kept in a secure storage location. The department responsible for administering the training records' database must be adequately resourced to ensure that all completed training forms, assessment and authorisations are entered into the electronic system as soon as possible.

The training database system should have the functionality to record the expiration dates of different types of training and authorisation, and have a method for flagging the impending expiry for action. Increasingly, mining operations are investing in site access control systems (security fences and gates) that will automatically notify and/or prevent site access to people whose competencies, authorisations, inductions or medicals have reached, or are close to reaching, their expiry date.

Training records are commonly summarised into a 'training matrix' showing the names of the people in a particular team, and the list of competencies and authorisations each person holds. This matrix may be designed to also show the competencies and authorisations that are required for each role, resulting from the training needs analysis discussed above. This training matrix can be printed into a hard copy chart and distributed to front-line supervisors and contractor supervisors as a quick reference to confirm who in their team has which competencies, authorisations and qualifications.

In addition to this hard copy training matrix, each employee and their supervisor should ideally be able to access the electronic training records database at any time of day, and any day of the week. This access is necessary should the person or their supervisor need to check the validity of a competency or authorisation prior to commencing a particular task.

2.5.3 Job safety analyses and safe working procedures

The nature of the work in the mining industry means that much of the focus in safety performance is on the behaviours of people, and in particular the front-line workers and supervision. This is in contrast to a more process-safety focus in processing and other heavy industries where work is more mechanised and safety is controlled more by hard engineering controls.

The dependence the industry has on the behaviours of our workforce for safety means that specific risk management practices must be developed for use at the front-line level. The risk management practices, and the procedures put in place to manage them, must be tailored to the level of skill, experience and knowledge that our front-line workers and supervisors possess. Likewise, the procedures put in place must be simple and efficient to undertake while in the mine or in a field environment.

Safe working procedures (SWPs) are the fundamental type of document that details how specific tasks, jobs and work activities are to be completed. SWPs contain step-by-step instruction on how to perform a task, including the safety considerations, hazards and controls relevant to each step. SWPs must be developed based on some form of risk assessment that considers not only the best way to perform the task, but also the hazards involved in each step.

The mine should have a consistent template for safe working procedures that includes the title, date developed and date for review, the training and competencies required for the job, the tools and document references required for the job, a signoff and feedback section, and of course the individual task steps. SWPs should be stored in hard copy and electronic form, and must be easily and continually accessible to people who may have to perform any task covered by them. Folders of hard copy procedures are often provided in workplaces, in addition to electronic access via computers or kiosks.

Where a safe work procedure exists for a particular task, it is the responsibility of the work team to follow this procedure, unless they find any hazards or changes that increase the risk or mean that the task cannot be performed in the prescribed way.

In the case where the SWP cannot be followed, or where an SWP does not exist for a proposed task, then a job safety analysis (JSA) must be completed before the work commences. A JSA is essentially a blank template for an SWP, and is primarily used to perform a risk assessment on the task by the people who will work on it.

A JSA is a simple form of risk assessment that requires the team who will work on the job to list the steps they intend to take, the hazards that exist during each step, and the controls they plan to put in place to address these hazards and reduce the risk to an acceptable level. Some forms of JSA document will also require the work team to assess the level of risk using the site's risk matrix. The JSA form will also have sections for the team to describe the job being undertaken, the people involved, and for the team to signoff their understanding and agreement. It is usual practice for a JSA to require authorisation from the team supervisor prior to work commencing.

It is usual for a completed JSA to be kept on the job site during the works, and for each new person coming to the job to be required to review and 'sign on' to the JSA document. This process ensures that all people on the job are aware of the procedure being followed, and more importantly aware of the hazards that exist. Upon completion of the job, JSAs are submitted for review, filing and for development into an SWP. A JSA may be converted into an approved safe work procedure if the job is likely to be repeated. This process means that the next work group performing the task can refer to the existing SWP rather than start from scratch with a blank JSA template.

All employees and contractors should be trained to complete a JSA in the workplace, and trained in the fundamental principles of hazard identification and risk assessment. They should also be made aware of the situations in which an SWP, JSA or other form of risk assessment are to be used.

2.5.4 Substance abuse

Most health and safety legislation contains requirements for workplaces, including mines, to be free from the use of alcohol and illicit drugs. Beyond this requirement, there is a responsibility on mine management to ensure that people working at the mine are in a fit state to perform their work, such that their mental and physical condition does not present an unacceptable risk to themselves or others.

One factor that can lead to a person's fitness for work being less than adequate is the use of substances such as alcohol and drugs (including prescription, non-prescription and illegal drugs). The use of these substances does not have to occur at the worksite for their fitness at work to be reduced.

The mine must have a policy and procedures for managing the risks of substance abuse and fitness for work. The policy and procedures should align with the relevant legislation, and reference the national standards for fitness for work and the testing and detection of substance abuse. The policy and procedures should cover the testing of workers prior to commencing work, and a system for self-reporting of potential impairment. This impairment may result from the use of legal medication, and the procedures should promote and support people to self-report on their own physical state.

Beyond this self-reporting the mine must have procedures for ensuring that people do not work on site in an unfit state or under the influence of any substances that may impede their safety performance.

The organisation should also have in place policies and procedures for assisting employees and contractors who need help with substance abuse or other issues outside of the work environment. The organisation has two responsibilities, first to ensure all persons can work safely on site, and second to support the well-being of their workers both inside and outside of work.

2.5.5 Fatigue management

Shift workers are a very special group of employees who ask a lot from their bodies, their families and their friends. Shift workers need to take OH&S needs seriously. Family and social support for a shift work lifestyle can go a long way towards assisting the individual to manage shift work and fatigue.

Shift work can affect work performance if not managed properly, as sleep problems reduce levels of alertness and concentration, impair hand-eye coordination, increase stress and increase error rate. In the long term shift work can also impact on the health of the worker, particularly the digestive system if not properly managed.

To manage shift work and reduce the effect of fatigue, responsibilities lie with both the employer and employee.

EMPLOYER RESPONSIBILITIES

- Ensuring safe work practices (eg sensible overtime procedures)
- appropriate and safe roster design to allow for adequate recuperation
- ensuring good work systems (eg scheduling work at appropriate times of the day).

EMPLOYEE RESPONSIBILITIES

- Lifestyle management (including the use of drugs and alcohol)
- taking adequate rest
- fitness for work
- incidence reporting (of fatigue-related incidents)
- diet, including hydration.

There are a number of guidance notes and guidelines that have been developed by different jurisdictions that provide information on management of hours of work and fatigue, including:

- Department of Employment, Economic Development and Industry Queensland, guidance note for management of safety and health risks associated with hours of work arrangements at mining operations, April 2001 – currently under review

- Commission for Occupational Safety and Health and the Mining Industry Advisory Committee, Western Australia, code of practice working hours 2006 and associated risk management guide
- Mine Safety Advisory Council of New South Wales, fatigue management plan, 2010 and associated fatigue risk management chart.

These guidelines outline the high risk factors and processes for managing them; they offer guidance on shift length and roster cycle design.

As well as the factors affecting fatigue at work care needs to be taken to manage potential fatigue impacts during the commute to and from work. The time taken to commute should be considered in any calculations relating to hours awake and hours available for rest. These become even more important when other exacerbating factors like heat and humidity are present.

Rosters should be designed to allow adequate breaks within shifts and between shifts to allow sufficient rest and maintain alertness. Roster design should be undertaken in conjunction with the workforce and take into consideration local conditions. Good shift design can also minimise inattention and boredom, utilising job rotation where possible, and appropriate break patterns.

Fatigue management plans are required under Queensland mining safety and health legislation under the fitness for duty provisions, and similar requirements to eliminate and/or control the risks associated with fatigue exists in the New South Wales mining safety and health legislation; as well as defining the hours of work. A key component of any fatigue management plan is the education and awareness process. In addition the plan should include an employee assistance process to deal with any personal issues that may impact their capacity for restful sleep.

2.6 FURTHER READING AND PROFESSIONAL DEVELOPMENT

One of the findings from the inquiry into the Moura No 4 mine disaster in 1994, was that there was a need to have a system of maintenance of competence for mine officials. While there have been developed competence standards and various assessment processes, it still largely remains up to the individual professional to undertake a professional development program. To a limited extent, programs such as the AusIMM Chartered Professional program audits and audits conducted as part of the registration of Professional Engineers in Queensland, provides third-party verification that some effort is being applied.

A key part of such professional development programs is the undertaking of reading and conference and course participation. In the area of health and safety, the community's expectations of what is leading and adequate practice evolves with both technical change and changes in social attitudes and standards.

A number of government and non-government organisations at both the national and state level have developed and are continuing to develop codes of practice, standards and guidelines to better identify hazards and to assess and manage risk in the workplace.

At the level of the Commonwealth Government, Safe Work Australia has been developing a number of codes of practice to control hazards (Safe Work Australia, 2012). These are outlined in Table 2.6.1.

TABLE 2.6.1
Codes of practice for hazard control.

How to Manage Work Health and Safety Risks	Hazardous Manual Tasks
Labelling of Workplace Hazardous Chemicals	Managing the Risk of Falls at Workplaces
Preparation of Safety Data Sheets for Hazardous Chemical	Confined Spaces
Managing Noise and Preventing Hearing Loss at Work	Managing the Work Environment and Facilities
Work Health and Safety Consultation Cooperation and Coordination	Managing Risks of Hazardous Chemicals
First Aid in the Workplace	Managing Risks of Plant in the Workplace
Construction Work	Excavation Work
Preventing Falls in Housing Construction	Demolition Work
Managing Electrical Risks at the Workplace	Welding Processes

Safe Work Australia is in the advanced stages of developing further codes of practice as shown in Table 2.6.2.

Safe Work Australia is also in the advanced stages of developing further codes of practice including a number of mining specific codes, as outlined in Table 2.6.3.

TABLE 2.6.2
Further codes of practice.

Preventing and Responding to Workplace Bullying	Spray Painting and Powder Coating
Safe Design of Building and Structures	Abrasive Blasting
Safe Access in Tree Trimming and Arboriculture	Preventing and Managing Fatigue in the Workplace

TABLE 2.6.3
Mining specific codes of practice.

Work Health and Safety Management Systems	The Mine Record
Managing Naturally Occurring Radioactive Materials	Mine Closure
Strata Control in Underground Coal Mines	Ground Control for Underground Mines
Roads and Other Vehicles Operating Areas	Health Monitoring in Mining
Inundation and Inrush Hazard Management	Ventilation of Underground Mines
Emergency Response at Australian Mines	Ground Control in Open Pit Mines
Survey and Drafting Directions for Mine Surveyors	Underground Winding Systems

Also emanating from the Commonwealth Government through the Department of Resources, Energy and Tourism (2012a) are a number of handbooks that address environmental and related health issues. This work is summarised in 'A Guide to Leading Practice Sustainable Development in Mining (New)' (Department of Resources, Energy and Tourism, 2012b). These handbooks include those listed in Table 2.6.4.

The Safety Institute of Australia (SIA) and associated professional organisations in the OH&S area, have had a long-running discussion on the topic of 'What is the scope of health and safety in the workplace?' In 2012, the SIA Health and Safety Professionals Alliance (2012) launched a web site titled the Body of Knowledge that encompassed this work. This extensive

work provides a linkage between OH&S professionals, educators and organisations that use or employ the services of OH&S professionals, such as the mining industry. Tables 2.6.5 and 2.6.6 subdivide the 39 chapters into strategic and hazard specific issues.

TABLE 2.6.4

Environmental and health-related handbooks (published by the Department of Resources, Energy and Tourism, Commonwealth Government).

Airborne Contaminants, Noise and Vibration	Mine Closure and Completion
Biodiversity Management	Mine Rehabilitation
Community Engagement and Development	Risk Management
Cyanide Management	Stewardship
Evaluating Performance: Monitoring and Auditing	Tailings Management
Hazardous Materials Management	Water Management
Managing Acid and Metalliferous Drainage	Working with Indigenous Communities

TABLE 2.6.5

Chapters covering strategic safety issues on the Body of Knowledge web site.

Strategic issues			
1	Conditions of Use – Contents	13	Human Psych Principles
2	Introduction	14	Human Principles of Social Interaction
3	Generalist OHS Professional	15	Hazard as a Concept
4	Global Work	31	Risk
5	Global Safety	32	Models of Causation Safety
6	Global Health	33	Models of Causation Health Determinants
7	Foundation Science	34	Control Prevention and Intervention
8	Socio Political Law	35	Control Mitigation Emergency Planning
9	Socio Political Industrial	36	Control Mitigation Health Impacts
10	The Organisation	37	Introduction to Practice as a Concept
11	Systems	38	Practice Model
12	Human Biological Systems	39	Practice Critical Consumer Research

TABLE 2.6.6

Chapters covering hazard-specific safety issues on the Body of Knowledge web site.

Specific hazards			
15	Hazard as a Concept	23	Electricity
16	Hazard Biomechanical	24	Ionising Radiation
17	Chemical Hazards	25	Non Ionising Radiation
18	Biological Hazards	26	Thermal Environment
19	Psychosocial Hazards	27	Gravitational Hazards
20	Fatigue	28	Plant
21	Bullying Aggression and Violence	29	Mobile Plant
22	Noise	30	Vehicles and Occupational Road Use

The particular relevance to the mining industry is that the body of knowledge is a guide to hazard identification, risk assessment and hazard control. It also provides a mechanism to develop more meaningful dialogue between the industry and health and safety professionals.

The various state government departments that have responsibility for mining health and safety have a wealth of published data relating to mine health and safety. In particular, those departments in New South Wales, Queensland and Western Australia have extensive resources. They also provide safety alerts on emerging safety issues and a mines inspection function as well as investigating incidents.

Collective organisations of mine operators, such as the Mineral Council of Australia, the New South Wales Minerals Council, the Queensland Resources Council and the Chamber of Minerals and Energy of Western Australia have departments that deal with and provide information in mining health and safety issues. These organisation are also pivotal in organising conferences of mine operators to discuss mine health and safety issues.

Several other organisations have mine health and safety functions, particularly in the research areas. Such organisations include SIMTARS, Coal Services Limited, University of New South Wales and the University of Queensland.

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CHAPTER 3

ENVIRONMENTAL MANAGEMENT

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Located in the Star Mountains of the Western Province, Ok Tedi Mining Limited (OTML) is the leading producer of copper, gold, and silver concentrate in Papua New Guinea (PNG). The operations comprise the Mt Fubilan deposit and process plant; the Bige riverine rehabilitation and pyrite concentrate storage operation; port facilities in Kiunga; and the Tabubil Township, home to over 10 000 people. In January 2011, OTML purchased back and cancelled the shares of the Canadian shareholder Inmet Mining Corporation (Inmet). The buy-back increased the proportionate ownership in OTML by PNG Sustainable Development Program Ltd (PNGSDP) to 63.4 per cent and the Independent State of Papua New Guinea to 36.6 per cent. OTML operates to provide 100 per cent of the benefits to Papua New Guineans. The business is run as a partnership comprising workforce, communities, contractors, suppliers and shareholders. Ninety-five per cent of the workforce comprises Papua New Guineans and OTML procures, on average, more than 81 per cent of goods and services from Papua New Guinean businesses. Since the exit of BHP Billiton in 2002, OTML has contributed PGK 516 million (US\$181 million) to communities affected by their operations and has paid PGK 16.7 billion (US\$5.9 billion) in dividends, royalties and taxes. In their 30 years of operation OTML has produced over 4 126 000t of copper; 12 960 000 oz of gold and 26 350 000 oz of silver and generated a revenue totalling over PGK 41 billion (US\$17.7 billion). OTML's objective is to demonstrate strong corporate responsibility and support positive development while generating value through high performance, safe work practices and industry competitiveness.

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3.1 SHARED VALUES FOR ENVIRONMENT PROTECTION

Mining is fundamentally a process of selection and it has, and always will have, a direct and an indirect impact on the environment. Early texts, such as *De Re Metallica* (Agricola, 1556, originally published in Latin), described the unwanted consequences of mining, such as the destruction of forests and the pollution of river systems and the resulting community concerns.

The General Assembly of the United Nations (UN) established the World Commission on Environment and Development and in late 1983 asked that Commission to formulate ‘a global agenda for change’. That 21-person multicultural Commission, chaired by a former Prime Minister of Norway, Gro Harlem Brundtland, conducted a wide-ranging investigation into many issues. In 1987 it completed its work and reported to the General Assembly. The report, titled ‘A Common Future’ was also published in book form and became a non-fiction best seller. This report can be considered as the starting point of general awareness of the concept of sustainable development, a concept that is now endorsed by the majority of the mining industry globally.

Following this report’s publication in 1987, the UN held a Summit of Heads of Government (SHoG) in Rio de Janeiro in 1991 to address the issues raised by the report. One outcome of this SHoG was Agenda 21, a document that set out what needs to be achieved to attain sustainable development on a worldwide basis.

In 1999 the World Business Council for Sustainable Development (WBCSD) contracted the International Institute for Environment and Development (IIED) to identify the state of the mining industry in addressing Agenda 21. The IIED in turn created the Mining, Minerals and Sustainable Development (MMSD) Project to conduct a participatory analysis of how the mining industry could contribute to the global transition to sustainable development. This project identified nine major challenges ‘across the world’. One of the nine challenges was ‘How can environmental management in the mining and metals industry be improved?’ This topic concentrated on three aspects of the mining industry, namely large volume waste, abandoned mines and closure.

The MMSD project published its report titled ‘Breaking New Ground’ in 2002 (Mining, Minerals and Sustainable Development Project, 2002) and this report was presented to a subsequent SHoG held in Johannesburg in 2002. While it covered all nine identified major challenges and outlined various agendas for change the report concentrated on the three aspects named above, where the mining industry could contribute towards sustainable development.

The President of the WBCSD, Dr Bjorn Stigson, had a very clear understanding of what sustainable development meant in the context of the mining industry. In a meeting held as part of the lead-up to the Johannesburg SHoG he summed it up as ‘Leaving a positive legacy while exploiting the resource’.

Modern miners have recognised their role in attaining the goal of worldwide sustainable development status and in particular the requirement to manage their operations in such a way as to minimise the unwanted and often unnecessary adverse environmental impacts of their industry and so retain their social licence to operate.

In particular there has been a recognition that the only certainty for any mining operation is that the operation will eventually close!

3.2 ENVIRONMENTAL STRATEGY FORMULATION

The life cycle of a modern mine typically includes the following stages: exploration and feasibility studies, detailed planning and construction, mining operations and closure. As mining is often said to be a temporary land use then the use of the mined land after operations needs to be clearly understood from the earliest practicable stage of the mine development to allow for the optimal closure of the mine.

Managers likely to be involved in mining projects are typically consulted at the feasibility and detailed planning stages and become the key personnel during the longest and most intensive stage of mining, the operations. It is important to recognise that many decisions made at the feasibility stage, such as where to locate the tailings facility, waste landforms and selection of the mining process options, will have major impacts on the overall environment. An awareness of this by the feasibility and detailed planning teams will enhance the desired environmental performance of the operation.

Environmental management in a mine is a multi-disciplinary task that requires the close interaction between specialists from a range of fields, including, but not limited to mine planners, ecologists, geotechnical engineers, hydrologists, mine, maintenance and process plant operators and rehabilitation specialists.

3.2.1 Environmental management tools

Over the past 20 years or so a wide range of environmental management documents have been developed for the mining industry by industry organisations, governments, individual companies and academic organisations. Many of these documents have been, and are being, updated as new techniques are tested and real data on the environmental effectiveness and operational practicability of these techniques are being evaluated.

Given the unique environmental and economic aspects of each mining operation it is unlikely that all the required detailed assistance for environmental management of any particular operation will be found, even after an extensive literature survey. However, the general principles are very well documented and will provide sound guidance to managers who then need to develop their own site-specific environmental management tools.

A list of suggested references is given at the end of this chapter.

3.2.2 Environmental policy statement

An organisation's or mine's environmental policy statement is a clear definition of an organisation's environmental commitments. As such it provides a unifying vision of environmental principles and fundamental goals of the organisation, setting the basis all of the environmental management activities and decisions taken by the organisation or mine. It is also a public expression of those principles.

The environmental policy statement provides a foundation and a focus for the comprehensive environmental plans and practices that need to be developed for each operation.

It is common for an environmental policy statement to include commitments, such as:

- comply with relevant environmental legislation and regulations and similar requirements, such as industry association policies and best industry environmental management practices
- maintain the environmental policy, communicate it to all employees, and communicate relevant components of the policy to all engaged contractors
- make the environmental policy statement available to the public
- continually improve environmental management measures and practices, including ongoing employee education
- focus on environmental harm prevention, where practicable, rather than subsequent treatment.

3.3 ENVIRONMENTAL MANAGEMENT STRUCTURE

3.3.1 Mining life cycle

The mine life cycle typically includes the following phases: exploration, feasibility, planning, construction, operations and closure or completion.

The activities typically required during the mine life cycle may include:

- exploration activities, such as line cutting, access road construction, drilling, trenching and bulk sampling
- development of mine workings and construction of associated infrastructure
- extraction of ore
- ore processing
- management of waste rock, tailings and other wastes
- decommissioning of the mine
- rehabilitation of the mine site
- transfer of responsibility of the mine site to a third party (often government).

The phases form a continuum that is the whole mining project from concept to completion. All actions taken in the early phases of the project will have an impact on all subsequent phases of the project and should be taken with the final completion of the project in mind.

Potential environmental concerns associated with mining include:

- impacts on terrestrial ecosystems (flora and fauna)
- impacts on aquatic and marine ecosystems
- impacts on local and regional surface water and groundwater
- noise
- off-site wastewater discharges from mining, ore processing and mine wastes storage facilities
- releases of airborne particulate matter and air emissions from operating equipment and other processes
- accidental releases of pollutants
- long-term chronic pollution (eg acid and metalliferous drainage)
- aesthetic impacts, such as alteration of landscapes
- direct and indirect social impacts, such as impacts on recreational activities.

3.3.2 Environmental impact assessment

The environmental impact assessment (which may be referred to by many different names in various jurisdictions) is a planning and environmental management tool that should be developed as early as practicable in the life of a project. This assessment is used to predict, analyse and interpret the effects of a specific project on the environment and should identify the measures that could be used to avoid or mitigate potential adverse environmental impacts.

In Australia, the considerable majority of new mines and significant expansions of existing mining operations are required to develop environmental assessments under the requirements of state, territory and/or federal legislation. These assessments are then submitted to the authorities prior to the proposed mining being authorised by the responsible governments. Authorisation for the proposed operation to proceed may be withheld if the environmental assessment is considered to be deficient by the authorities and therefore early contact with regulatory authorities should assist in identifying assessment requirements and facilitate an efficient and effective environmental assessment process. It is common for the governments to require the environmental assessments to consider alternative development proposals and justify the selected development method.

The environmental assessment is the first step to developing a systematic feedback process that can verify the environmental assessment predictions. The baseline data obtained during the environmental assessment process can be compared with monitoring data collected later in the mine life and is used to assess any changes in environmental conditions relative to the conditions that existed before mining commenced and verify the environmental predictions.

3.3.3 Risk assessment

Environmental risk management involves the identification of factors that could potentially affect a mining operation and the identification and implementation of control measures to eliminate or reduce risks that are considered unacceptable.

As part of its Leading Sustainable Development Program (LSDP) for the mining industry series, the Commonwealth Government of Australia published a booklet titled Risk Assessment and Management (May 2008). This provides a good background on environmental risk management in the mining industry and contains a number of examples of case studies.

In Australia and New Zealand a generic framework exists for establishing the context, identifying, analysing, evaluating, treating, monitoring and communicating risk – this framework is the AS/NZS 31000:2009 Risk Management Standard (Standards Australia/Standards New Zealand, 2009).

Effective risk management seeks to ensure that:

- the health, safety and wellbeing of employees and the public is not compromised
- environmental values are not unnecessarily impacted
- financial performance of the organisation is protected
- the organisation earns its social licence to operate in the eyes of local communities, regulators and other stakeholders, based on performance.

Persons responsible for managing environmental risks in the mining industry need to recognise the uncertainty and unpredictability inherently associated with natural processes. The paucity of some key information may require the practical implementation of the Precautionary Principle, which was defined in the 1992 Rio Declaration on Environment and Development as:

Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

Some aspects of the mining industry have been recognised as having an inherent potential for major accidents that could injure or kill employees and members of the general public, damage the environment and/or cause serious loss of production, thus reducing financial benefits. One such aspect is the management of tailings and this historically accident-prone aspect (ICOLD Bulletin 121, 2001) has resulted in the development of a specific risk assessment protocol, Australian National Commission on Large Dams (ANCOLD) (Guidelines on Risk Assessment, October 2003).

3.4 ENVIRONMENTAL MANAGEMENT PROCESSES

3.4.1 Environmental management systems

Environmental management systems (EMS) may be used by mines to manage all environmental aspects throughout the mine life cycle in a manner that is fully integrated with all other management and operational considerations.

The EMS provides a structured approach to fulfilling the mine's environmental policy through a system of ongoing planning, implementation, checking, corrective action and management review. This feedback process promotes continual improvement to achieve objectives and targets and fulfil the environmental policy over the life of the mine.

The development, implementation and ongoing maintenance of a comprehensive EMS, with regular reviews/audits and continual improvement, is ideally suited to mine operations where the physical changes that are inherent in mining result in a very real need for waste management plans, rehabilitation plans and other management practices, including pollution mitigation plans and closure plans, all of which need to be progressively updated.

Site-specific environmental management systems (EMS) should be developed, implemented, maintained and updated in a manner that is consistent with a recognised standard or system, such as ISO 14001, developed by the International Organization for Standardization (ISO, 1996). This publication has a related publication, the ISO 14000 Toolkit, which is designed to assist in meeting ISO 14001 and includes:

- an ISO 14001 based EMS policy manual
- a set of top-quality ISO 14001 procedures
- a detailed implementation guide (with task lists)
- a collection of forms and templates to help users manage the compliance process
- a comprehensive audit plan/checklist
- a comprehensive ISO 14000 training and awareness presentation.

Environmental management systems should be used to manage all environmental aspects of the activities over which an operation has control, or which it can reasonably influence, including transport of mine products and mine consumables, such as fuel and reagents.

Elements of an EMS should include:

- assessment of significant environmental impacts of the project
- identification of legal and other applicable requirements

- a clear definition of objectives and targets to meet the organisation's environmental policy
- accountability for environmental action across the organisation
- stated procedures to translate the environmental policy into day-to-day practices
- monitoring, checking and auditing of the system
- identification of actions to provide continual improvement
- training and communication for general awareness.

The aspects of a mining operation that will normally have environmental impacts include:

- waste generation and disposal
- emission to air (including greenhouse gases)
- noise and vibration
- releases to underground and surface water
- use of hazardous materials
- use of natural resources
- changes to ecosystems
- land use.

Conforming with the ISO 14001 requires an EMS to have:

- a defined environmental management structure
- defined responsibilities
- trained, competent personnel able to manage the environmental aspects of their roles in the organisation
- internal and external communications procedures
- effective document control procedures
- operational control of environmental aspects
- environmental emergency response procedures and capability.

3.4.2 Environmental management plans

Site and operation-specific environmental management plans should be developed, implemented and updated throughout the mine life cycle. The plans should include, as a minimum, descriptions of the following:

- information about the owner/operator of the mine and information about the mine itself, including a description of the mining and ore processing methods used and the geographic setting of the site
- the organisation's environmental policy statement
- environmental performance requirements
- air quality management programs
- water quality management programs
- management programs for tailings and waste rock
- land management programs
- pollution prevention planning
- management of garbage and other waste materials
- environmental objectives and targets along with schedules for achieving objectives and targets
- environmental management programs and auditing

- relationships with stakeholders, including local communities
- procedures for communicating with regulatory agencies and stakeholders
- periodic review of the environmental management plan for effectiveness and continual improvement
- employee awareness and training.

Mining operations in Australia have a number of environmental aspects that require specific environmental management plans and four of these aspects, waste rock management, acid and metalliferous drainage (AMD), tailings management and closure, are outlined below to suggest how suitable EMPs could be developed for any specific operation.

EXCAVATED WASTE MANAGEMENT

For many mines the management of excavated waste is the largest operating cost and largest bulk handling activity for the project. To minimise operating costs and efficiently manage this unwanted product of the operation in an environmentally acceptable manner requires careful planning and implementation.

An inventory of all wastes that will be excavated, handled and disposed of during the operation should be developed.

The inventory should clearly document the quantities, physical and chemical characteristics and potential hazards (AMD potential, asbestiform minerals, etc) and other characteristics (dispersive clays) of the excavated wastes that will be generated for each section of the mineral deposit. It should also state the quantity of waste rock to be managed in each operating period (say per quarter or per year), together with the techniques used for excavating, handling and disposal of waste rock.

Development of the inventory will normally commence with the geological data obtained during exploration and will be continually developed during the operation as more data on the chemical and physical characteristics of the solid waste becomes available.

Using the data on the material characteristics of the wastes rock, suitable disposal sites can be identified and suitable waste landforms designed, using a risk assessment process.

Waste landforms should be designed taking into account:

- scheduling of production of the various excavated wastes
- the behaviour of these wastes during weathering
- the potential for wind and water erosion to cause unwanted environmental impacts as a result of run-off and seepage
- the geotechnical stability of the waste landforms, including the foundations
- leading available or most applicable technology for stability and safety
- the location of sensitive receiving environments and water resources within and external to the mining lease
- the visual impact of the completed landforms
- risk assessment in the case of severe climatic events.

Numeric modelling tools are available that can be used to estimate the long-term physical and chemical behaviour of waste rock. While these tools do not provide an absolute prediction of waste rock dump performance, they do provide indicative relative performance information when several waste landform design configuration alternatives are being considered.

The design of the final landform can be undertaken using the normal mine planning data and will enable a mine to place its waste rock in a cost-effective manner by minimising double handling and post-operational reshaping of the landforms to meet the required environmental outcomes.

During operations waste rock structures should therefore be monitored to verify that the potential modes of structural failure and potential environmental risks posed by waste disposal facilities remain within the design parameters.

ACID AND METALLIFEROUS DRAINAGE (AMD)

This aspect is well covered in the handbook of that title produced by the Commonwealth Government of Australia as part of the Large Scale Development Project (LSDPs) for the mining industry series. Other useful references are included at the end of this chapter.

AMD is primarily initiated by the exposure to oxygen of minerals that contain reactive elements (commonly sulfides). The most commonly encountered in mining are the acid-generating sulfide minerals include pyrite (FeS_2), pyrrhotite (FeS), marcasite (FeS_2), chalcopyrite (CuFeS_2) and arsenopyrite (FeAsS). AMD is a natural phenomenon that over a geological time-scale has formed gossans and laterites. Mining activities that expose these common sulfide minerals to air, such as excavation of rock, exposure of rock in pit walls and underground openings, as well as the construction of waste rock dumps and tailings storage facilities all have the potential to generate long-lived AMD. The processing of ore by grinding also contributes to the AMD potential of sulfides by increasing the minerals' surface area exposed to oxygen.

While the overall causation of AMD is well understood, different reactions may be prevalent in different mining environments, and conjecture remains about the exact mechanisms and chemical and biological drivers of the process. Some common observations of AMD are:

- onset may occur some significant time after mining operations begin, with the result that AMD is commonly a greater problem after mining ceases than during mine production
- once initiated, acid production may increase and there is a tendency for the quantity of AMD to escalate
- a return to former anoxic conditions will probably not halt AMD.

AMD, once started, can be a largely intractable problem for a potentially very long time, with some known AMD sites having been active for many centuries.

Prevention or minimisation of AMD therefore requires effective management of mining operations to preclude the onset of sulfide oxidation.

The first step in effective management is the evaluation of AMD risk. This should commence during the exploration phase and should be reassessed at intervals throughout the life of the project. As part of an operation's mine planning procedures the potential impacts and management costs of disturbing sulfide minerals should be assessed prior to that disturbance occurring.

Sample selection for AMD assessment is a critical task and must be given careful consideration at all stages of a project. The samples should represent each geological category of material that will be mined or exposed, including each waste and ore type, for current and projected mine plans. Table 3.4.1 shows the number of samples required to assess AMD, as recommend in Maest *et al* (2005).

TABLE 3.4.1Recommended number of samples for each rock type (Maest *et al*, 2005, reproduced with permission).

Mass of each separate rock type (tonnes)	Minimum number of samples
<10 000	3
<100 000	8
<1 000 000	25
10 000 000	80

The objective of the sampling is to obtain sufficient samples to adequately represent the variability/heterogeneity within each geological unit and particularly each waste type.

Drilling and sampling undertaken during the assessment of a mining project will inevitably focus on ore zones. However, the objective of mining is to process and sell the ore and then remove it from the site, while all waste will remain on site in perpetuity. Adequate sampling of host and country rock is therefore essential to assess what long-term legacies will remain at the site and develop suitable waste management practices to minimise adverse environmental impacts.

As a minimum all exploration drill hole samples should be assayed for total sulfur content to provide baseline data and enable the initial development of block models and production schedules by geochemical waste types. These initial investigations will assist in identifying potential areas of concern in and around the deposit that will require more detailed testing.

Management strategies that minimise the disturbance of AMD materials are considered preferable to strategies that rely on post excavation treatment as many post excavation treatment strategies that have been tried have proved to have been of limited long-term effect. This has shown to be particularly so when there has been a significant time delay between excavation of the AMD materials and the implementation of the treatment strategies (Taylor *et al*, 2003).

Essentially these treatment strategies can be grouped into three types:

1. those that prevent acid formation being initiated (reduce the availability of oxygen to a practical minimum)
2. those that limit the availability of water to transport the acid and dissolved pollutants (encapsulation)
3. those that neutralise the acid that has formed.

The selection of optimal AMD treatment strategy (or strategies) for any operation is site specific as it depends on a wide range of factors, including climate, topography, mining method, material type, mineralogy and available neutralisation resources at the site. Placing recently excavated AMD materials under water is reported to be an effective strategy in temperate regions of the world, while the reports from the Rum Jungle (White's Waste Dump) encapsulation (Taylor *et al*, 2003) highlight some of the practical challenges associated with encapsulation. Treatment of acidic discharge emanating from a mine site is normally considered to be a very long activity, probably extending for many centuries, as is demonstrated by many very old mines in Europe and by studies of recent North American mines.

It should be noted that long-term containment of AMD-generating wastes usually requires specifically engineered cover systems, which in turn require a high degree of quality control during construction to be effective.

The ongoing identification of AMD-generating waste during mining and the effective segregation of these materials at every stage of mining is an essential first step in implementing an effective AMD minimisation strategy.

A range of reports and guidance documents, including many case studies has been published by the Mine Environmental Neutral Discharge (MEND) program, jointly funded by the Mining Association of Canada and the Canadian Government, while the International Network for Acid Prevention has published the Global Acid Rock Prevention Guide (GARD) (International Network for Acid Prevention (INAP), 2010).

The development of practical AMD management practices at mines often requires the involvement of specialist experts and it is important to note that simple compliance with pertinent government regulations and license requirements does not necessarily guarantee AMD is being managed in the most practical, effective or economic manner.

TAILINGS MANAGEMENT

Since the end of the Second World War poor management of tailings by the mining industry has caused more deaths in the general public than any other aspect of mining (over 500 and still counting) (Mining Journal Research Services, 1996). Major tailings mishaps still happen at an unacceptable rate (eg Kingston fossil plant, Harriman, Tennessee, USA, 2008 – no deaths, but significant environmental and infrastructure damage; Karamken, Magadan region, Russia, 2009 – one death and Kolontár, Hungary, 2010 – ten deaths). ICOLD Bulletin 121 (2001) reports the most common causes of reported tailings incidents as lack of control of the water balance, inappropriate site selection, lack of quality assurance and quality control during embankment construction and a general lack of understanding of safe operating practice for the facility.

An increasing international awareness of the risk potential of tailings (mis)management has resulted in the publication of a number of guidelines and codes of practice, by governments and non-government (industry) organisations.

General tailings management is well covered in the handbook of that title produced by the Commonwealth Government of Australia as part of the Leading Practice Sustainable Development Program (LPSPD) for the Mining Industry series (2007).

The handbook states:

Tailings storage facilities should provide safe, stable and economical storage of tailings in such a way that presents negligible public health and safety risks and acceptably low social and environmental impacts during operation and post-closure.

There are many guidelines and other texts available to assist in the design and management of tailings facilities, but it needs to be recognised that ultimately each facility is a unique, purpose-built structure that must be operated within its design parameters if it is to meet the basic requirements described above.

Tailings are most commonly placed in above-ground storage facilities, which can vary considerably in configuration depending on the physical and chemical properties of the tailings, site topography and geology and climatic conditions. Generally speaking, operating techniques that minimise the slurry water in the tailings facility, such as thickening the slurry prior to deposition, reduce the risk of an operating accident and reduce the potential severity of such an accident, should it occur.

The overall design objective is to construct a facility (or facilities) that will retain the tailings at that site in the very long term (possibly millennia rather than decades). It is

recommended that a risk-based approach be used for all stages of tailings management, from original conceptual design to final completion (Australian National Committee on Large Dams Inc, 2011).

The design should incorporate sufficient flexibility to enable the effective management of changing circumstances. Some changes will be routine and anticipated, such as progressively raising the facility's embankments to accept future production or anticipated changes in tailings properties due to changes in ore type. Others will be unforeseen, such as unanticipated increases in production rates, changes in process technology that result in changes to tailings properties, other sources of ore being processed by the plant and early closure of the mine.

Water management of the facility is a critical aspect of safe operations. A detailed understanding of the facility's water balance should be based on a range of climatic and operational conditions, not just annual or monthly averages, as extreme, short-term inclement weather events often cause major tailings facility failures.

A tailings storage facility (TSF) is an ongoing construction site that is not completed until the last tailings have been deposited and the site made safe and stabilised for its post-mining life. The LSDP Tailings Management handbook recommends development of a specific tailings management plan for each tailings facility that should comprise the following:

- *A life-of-mine tailings storage facility plan* – stating how and where tailings will be stored over the life of the operation, the estimated budget (and schedule) and how construction will be staged.
- *Design criteria* – including the production requirements, geotechnical, geochemical, operational, closure, public health and safety, community and environmental performance objectives that the tailings storage facility is expected to achieve, at each stage in its life.
- *Design report(s)* – detailed designs for each structure or stage of the tailings storage facility, including drawings, to achieve the specified design criteria. This will include geotechnical, dam break studies and other investigations carried out in support of the design.
- *Construction report(s)* – a detailed report on the construction of the tailings storage facility as measured against the drawings and construction quality plans. This should include as-constructed drawings and photographs to assist in the identification of risks going forward and in the back-analysis of issues arising.
- *Operating manual* – a document presenting the operating principles, methodology and associated resources and training, safety (or risk) management plan. The document should include surveillance and monitoring plans, including inspections, monitoring, water balance and performance reviews, trigger values, emergency action and response plan. The document should specify the steps to be taken in case of an emergency to minimise public health and safety, community- and environment-related risks and impacts if an incident occurs.
- *Closure plan* – the closure strategy that forms the ultimate objective of the tailings management plan.

The operating manual is a critical element in the successful management of a TSF. It is a dynamic document that will periodically require updating as operating conditions at the facility change over the life of the mine.

Mining operations using cyanide as a reagent in processing are directed towards the LPSPD booklet and the International Cyanide Management Institute for further guidance.

CLOSURE

The LPSDP handbook *Mine Closure and Completion*, published in 2006 (Leading Practice Sustainable Development Program for the Mining Industry series, 2006), specifically differentiates between the process of closing down a mine and attaining the goal of a completed mine, when the land affected by the mine can be relinquished to a third party (usually a government).

Because closure is the only certainty for any mine, closure planning should begin during the prefeasibility phase for any proposed mines and as early as practicable in the mine life cycle for existing mines.

It should commence with a clear definition of the final land use objectives for the site, which will normally involve the objective of the mining company relinquishing responsibility for the site some time after mining has been completed. This stage of planning should involve other stakeholders so that the finally adopted post-operational land use is agreed from the outset of the project.

Figure 3.4.1 illustrates the closure planning process that is often adopted for a greenfield mining operation. This schematic shows that as the project progresses more data becomes available, enabling more detailed closure planning to take place. Conversely, it also shows that as decisions are made over the life of the project, such as where to locate the TSF, the degrees of freedom available to the planners is reduced. Companies need to clearly recognise both of these aspects of closure planning process and should design the project from the outset with the final land use and other broad closure objectives as key design and planning considerations.

FIG 3.4.1 - Closure planning process (based on the Planning for Integrated Mine Closure Toolkit, International Council on Mining and Metals, 2008, reproduced with permission.).

Closure planning is a continually evolving process that should be considered at all stages of the project's life and should be incorporated into all aspects of project design, mine planning, construction and operation. Closure plans should identify measures to be undertaken during the operations phase that could facilitate the progressive rehabilitation of land disturbed during the mining operations.

Mining should be conducted in a manner that prevents or minimises adverse impacts and risks to the environment and human health after closure. Closure plans should identify site-specific objectives for mine closure and the criteria that will confirm when these objectives have been attained. Closure plans should detail the processes that will be used to decommission and rehabilitation of all aspects of the mining facilities, including:

- mining and ore processing facilities, including waste landforms and tailings facilities
- site infrastructure
- water and other waste management facilities (putrescibles, tyres, etc).

Closure plans should be reviewed and revised as necessary throughout the mine life cycle. The plans will become more detailed (Figure 3.4.1), incorporating updated data on all activities related to the mine and taking into consideration site-specific conditions and monitoring results. Closure plans may also be revised in response to:

- the results of progressive reclamation activities
- the results of tests to assess specific aspects of the closure plan
- public response to a proposed closure plan
- changes in mine operations, such as production rate or ore type
- changes in technology, such as improvement in technology for preventing or controlling acidic drainage
- changes in economic conditions, such as input costs and other economics related to mine closure
- unexpected or adverse climatic conditions encountered during the construction and operations phases of the mine life cycle.

The evolution of closure plans at many mines frequently sees three basic stages, which should blend into a continuum when closure planning becomes part of a mine's operational philosophy.

In the case of new mines, the first stage takes place during exploration, prefeasibility, feasibility/design activities. At this stage, closure goals and target outcomes are formulated in an iterative process with the prefeasibility and feasibility study teams and finally recorded as a conceptual closure plan, which is often submitted to government as part of the environmental approval process for the project.

The next stage is a long one that extends throughout the bulk of the mine life. It is the ongoing development in the light of practical operating experience and continued interaction with various stakeholders, including the local community and government organisations of a detailed closure plan (DCP). The DCP should be seen as a dynamic document that is continuously updated as the understanding of stated goals and completion criteria to assess attainment of those goals expands. This DCP should be used continuously during mine and other operational planning in order to efficiently meet the closure goals.

The evolving DCP is an increasingly detailed development of the concepts stated in the conceptual closure plan, with the ability to evolve in line with changing circumstances and perceptions of risks.

The final stage in the process of completing the mining operation is a decommissioning and closure plan, in many ways a mirror image of the detailed construction and project management plan used to construct the mine. It defines all activities needed to transition the mine from full production to final relinquishment of the land. It will often include the deconstruction of all built facilities, rehabilitation of all disturbed land and the monitoring required to verify when the final completion criteria have been met.

3.4.3 Environmental performance indicators

Environmental performance indicators should be developed to facilitate tracking of the mining facility's overall environmental performance through readily understood measures of the facility's environmental performance and effects.

3.4.4 Environmental monitoring

Environmental monitoring has two stages, the initial measurement and recording of collected data and the assessment of that data. Simple collection and recording of various data and passing that information to a third party (eg government) is of little practicable use in managing the environmental aspects of a mining operation, although it may be a legal requirement to do so. The collected data should be regularly assessed by the mining company and, if required, operational practices should be adjusted to attain the desired environmental objectives.

Environmental monitoring plans should be designed to remain in place throughout the mine life cycle, although unanticipated changes in the project may require the plans to be reassessed. They will be required for several different reasons, including:

- all environmental monitoring and reporting required under regulations and licences
- quality assurance and quality control (QA/QC)
- monitoring of releases to air, water and land
- monitoring of environmental performance indicators, including air and water quality and aquatic and terrestrial species and ecosystems.

Environmental monitoring should include specific plans to measure and verify all effects and end points that were predicted in the environmental assessment so that site management practices may be optimised.

When an environmental monitoring plan is developed it should clearly define:

- the applicable environmental standards and environmental quality objectives (eg water or air quality standards or other objectives)
- monitoring schedule
- sampling procedures (eg sample preservation requirements and chain of custody requirements)
- analytical methods (if any)
- quality assurance and quality control (QA/QC) procedures
- record-keeping protocol
- procedures for the assessment of monitoring results
- actions to be taken when 'trigger' values are noted
- procedures for reporting the results of monitoring
- procedures for following up on monitoring reports
- procedures for periodically reviewing and updating the environmental monitoring plans.

3.4.5 Emergency planning

The nature of most emergencies is such that the event or events are unexpected. These events can be initiated by factors within the mine, as happened at the Los Frailes tailings failure in Spain in 1998, or by factors external to the mine, such as the Queensland flood of 2011. It therefore follows that the scope of environmental emergency plans for any mine site should be broad and comprehensive in nature, and should go beyond any legislated requirements. This is particularly with respect to hazard identification, risk analysis and consequence as well as community involvement and communications.

The unexpected nature of most emergencies should not preclude the development of a site-specific organisational framework that will enable organisations to quickly respond to any environmental emergency.

The guidance document APELL for Mining: Guidance for the Mining Industry in Raising Awareness and Preparedness for Emergencies at Local Level (United Nations Environment Programme, 2001) covers risk factors specific to the mining industry, and describes how APELL can be applied to the mining industry.

3.4.6 Environmental auditing

Periodic environmental audits should be conducted to verify:

- that the site is operating in compliance with applicable regulatory requirements and appropriate non-regulatory and corporate requirements
- that the EMS and other environmental plans are still relevant and have been properly implemented and maintained.

All applicable government regulations or specific environmental approval conditions should be included in the audit criteria, and each audit should take into consideration the results of previous environmental audits. Environmental auditors should be qualified by virtue of their relevant experience and training, and audit team members should be objectively selected.

ISO 19011, Guidelines for Quality and Environmental Management Systems Auditing (International Organization for Standardization, 2002) implementation of the audit program.

3.5 STAFFING AND SKILLING THE WORKFORCE

3.5.1 Environmental training

An essential element in the environmental management at a mine is the effective training of all site staff, including all contractors. Procedures should be developed to identify the job-specific environmental training needs and ensure that all personnel receive the environmental training pertinent to their roles in the project.

All employees and service providers, including contractors should have general awareness environmental training (induction) including (but not limited to):

- the organisation's environmental policy and relevant environmental practices
- regulatory environmental obligations
- environmental emergency procedures, including spill prevention, reporting, response and evacuation procedures.

The training should be an ongoing process with regular refresher training for all employees and service providers. A record should be kept of all personnel attending environmental training together with an outline of the environmental training given, the training methods to be used and the required frequency of refresher training.

In addition to the general awareness training, specific environmental training needs for groups of employees or contractors (such as tailing facility operators or rehabilitation personnel) should be developed. Where practicable, operating manuals that incorporate environmental requirements should be developed for operating tasks and operators should be trained in correct operating procedure through the use of those manuals.

There is a strong similarity between safety training and environmental training and performance. In both cases training should extend to every individual associated with the operation as overall performance of the operation is determined by the personal attitude and actions of each individual, not by the professionalism of specialist staff.

3.6 MANAGEMENT OF EXTERNAL RELATIONSHIPS

3.6.1 Stakeholder engagement

An effective approach to stakeholder engagement (described in more detail in Chapter 4) starts early in a mine's development, well before construction and in the early stages of seeking environmental approval for a project. By the time a mine is operational, senior mine managers employing a best practice approach will be implementing a community engagement plan with well-established stakeholder relationships, which should lead them into early discussions about closure.

While many Australian state and federal legislative frameworks do not specify requirements for engaging communities about the operations of a mine, there has been increasing pressure from regulators and the public for the mining industry to effectively communicate with communities throughout a project's life cycle.

Key national and international mining guidelines (International Council on Mining and Metals, 2012) recognise that sustainable practices consider the views of community and other stakeholders. Good stakeholder engagement is a key factor in the measurement of corporate social responsibility and an effective tool for managing risk. Open and transparent dialogue with shareholders, government and communities reduces the potential for public outrage and controversy.

Some aspects of good external relations practices during the operation of a mine include the following:

- immediate disclosure of information regarding safety, environmental compliance or any other issues potentially impacting on external stakeholders and known to be of community concern
- regular provision of information about monitoring and management of issues known to be of concern to stakeholders
- regular interactions with community and stakeholders to find out their areas of concern and provide responses back on those points
- developing partnerships with community to play an active role in the mine's operation, eg as employees, contractors or trainees

- providing opportunities for stakeholders to visit the operation and interact with staff and management, where appropriate.

3.6.2 Identifying stakeholders

External stakeholders can be considered in the following categories – government, community and indigenous. Within each category it is possible to further identify stakeholders of primary and secondary status. Management, staff and contractors should be considered as internal stakeholders and their engagement needs should be addressed separately. Company shareholders can be considered external stakeholders and would fit in the community (primary) category.

GOVERNMENT (PRIMARY)

- State regulators responsible for approving the project
- local government authority where the mine is located
- federal regulators with a decision-making role
- local members of parliament (to the location of the mine).

GOVERNMENT (SECONDARY)

- State departments with no decision-making role now, but a potential role later
- broader government representatives, with an interest in the mine but no direct role.

COMMUNITY (PRIMARY)

- Shareholders
- landholders or residents on properties neighbouring the mine
- communities living near the mine
- local businesses or service providers
- local non-government organisations (NGOs), education providers, community associations.

COMMUNITY (SECONDARY)

- State-based NGOs/conservation groups with an interest in the mine
- broader community.

INDIGENOUS (PRIMARY)

- Traditional owner groups (for the land where the mine is located)
- native title claimants / native title holders (indigenous people who are not traditional owners, native title claimants or native title holders but live near the mine should be considered as primary community stakeholders).

3.6.3 Planning stakeholder engagement

The planning process for stakeholder engagement is crucial to its success. Some useful guides and reference documents are available to assist with this process (International Association for Public Participation (IAP2)). Employing a transparent process for stakeholder engagement represents an important risk management tool as it ensures open lines of communication between the operation and any people potentially impacted by the mine's activities or holding an interest in what goes on behind the mine gates.

Underlying principles to consider when planning stakeholder engagement include the following (International Finance Corporation, 2007):

- be targeted, engage the people most affected first
- engage people early
- provide information openly and honestly
- make the information meaningful to the people hearing it
- provide for a two-way dialogue with stakeholders
- document the concerns people raise
- provide feedback about their concerns
- make the engagement ongoing.

3.6.4 Indigenous stakeholders

Indigenous stakeholders need to be considered as part of primary community engagement strategies as well as targeted indigenous strategies. In many cases, there will be requirements for mine operators to consult with traditional owners as part of native title or cultural heritage legislation. Much of this consultation starts prior to construction and includes heritage surveys to seek clearances for ground disturbing work. Following the issuing of any clearances, mine managers remain obligated to report the discovery of any artefacts or remains during operations. A positive and ongoing relationship with local traditional owner groups will assist with the resolution of such issues if they arise.

Many mines are also looking to improve their indigenous employment rates or contribute to local community development funds so that indigenous people receive longer lasting benefits from the investment a mine creates. The principles of best practice for engaging indigenous people are the same as those described for the general community. Importantly, some of the techniques used to engage indigenous people will need to be specific to the target audience and culturally appropriate (International Council on Mining and Metals, 2010).

This topic will be dealt with in more detail in the following chapter.

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CHAPTER 4

STAKEHOLDER RELATIONSHIPS

Sponsored by:



KCGM manages the assets and operations of joint venture partners Barrick Australia Pacific and Newmont Australia Pty Ltd. Their combined ownership includes the Fimiston Open Pit (Super Pit), Mt Charlotte Underground Mine, Fimiston Mill and Gidji Roaster.

Located on the outskirts of Kalgoorlie-Boulder, approximately 600 km east of Perth, the Super Pit was born out of the days when small mines were owned by individual operators along 'the Golden Mile'; one of only four 50 Moz goldfields in the world.

Since gold's first discovery in Kalgoorlie in 1893, there have been 80 separate mining operations, 1200 different companies floated to exploit the Mile and well over 55 Moz of gold extracted.

The Super Pit is currently the largest gold producing operation in Australia; supported by a gold reserve that currently stands at 8.4 Moz. When completed, it is expected to be 3.6 km long, 1.6 km wide and up to 660 m deep.

The operation contributes approximately \$321 M to the local economy each year through salaries and wages and the use of local suppliers. This is complemented by an active community investment program that supports community and capacity-building activities; and a focus on local recruitment, which has been crucial to the continued success of the operation.

With KCGM's support, the City of Kalgoorlie-Boulder has grown into a sophisticated regional centre offering a fantastic lifestyle with services to match. The company remains focused on proactively consulting the community to ensure their views and expectations are accounted for in all stages of the mining process.

Mine closure is also an important consideration for KCGM. It is recognised that mineral resources are finite and the company has provided the community with a nominal date of 2021 to ensure that adequate closure planning can commence while feasible mining opportunities to extend the life of the mine are investigated.

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4.1 INTRODUCTION

In the mining industry, the term ‘stakeholder’ can encompass a variety of individuals, groups and organisations who are affected by a project, or by the actions of an organisation or by changes in a community or geographical area. A stakeholder is quite literally anyone who holds a ‘stake’ or interest in the project; they may hold a financial stake, as is the case for the employees, board members and shareholders of a company. Less easily defined are the ‘concerns’ or perceptions of members of the local community and common interest groups, or regulators, such as government departments and agencies.

There is much literature on stakeholder management and engagement (South Australia Chamber of Mines and Energy, 2012). Irrespective of the type of stakeholder or the stage of the mining project, there are a number of underlying principles that apply. The following points are a typical list:

- Always have a common understanding both within the organisation and with stakeholders of the objectives, aims, scope, roles and procedures for engagement. Typically there will be different views on some aspects of engagement, hence it is important to have an agreement on resolving conflict and the process for making decisions and evaluation.
- It is imperative that all stakeholders have ambitions that are realistic and achievable and the intended outcomes or targets are clearly understood by all.
- Everybody has limited time and therefore it is important to have precise objectives that address the very important concerns.
- Ensure engagement is genuine, allowing critical stakeholders to voice their concerns and questions. Never engage in a one-way interchange of information with no opportunity for genuine discussion.
- Do not think stakeholder engagement is purely a public relations exercise. Engagement should drive decisions.
- There are numerous stakeholders, not all of which have the same level of influence and willingness to engage. It is important to identify the appropriate stakeholders and engage stakeholder representatives who are able to make decisions for their constituents or group. Always strive to ensure that stakeholder engagement benefits the process and relationships and that all have the information and an understanding of how mining-related decisions will impact on them. Genuine stakeholder engagement will only take place if sufficient time, resources and people are made available.
- When communicating, it is important to be prepared and to plan well ahead. Always be responsive, consistent and timely with communication and allow for stakeholder feedback. Always have a communication plan and document the engagement rationale and processes.
- To be successful with engagement it is important to act fairly and be sensitive to perceived or actual power differences amongst the stakeholders. Always promote engagement processes that guarantee fair participation by all.
- Critical stakeholders will change through the stages of a mining project and different stakeholders may require the engagement to take place in different formats. At the exploration phase one-on-one meetings may be appropriate, but at the mining proposal phase, roundtable discussions, stakeholder panels or public presentations may be required to achieve the engagement objective.

- Mining operations are typically long-term projects and although they provide significant benefits to both the local and broader communities, successful long-term relationships must be established. Trust takes time to develop, particularly with community groups that have different customs and values.
- The engagement process must be carried out in an honest and accountable manner and be linked to project decision making and governance.
- Nobody is perfect and mistakes, errors and misunderstandings will always occur. When mistakes do occur they should be acknowledged, noted and used to improve the engagement and communication processes.
- Stakeholder engagement is often a journey of experiences that is expected to last for a long time. Remember to include stakeholders in achievements and successes as this will ensure continued long-term beneficial stakeholder relationships.

For a mine manager, relationships with stakeholders can be many and complex. They can also overlap as a stakeholder can be an employee, a shareholder of a company and a member of the local community. The mine manager also has a financial stake as an employee of the organisation and has a community concern as at least a part-time resident in the local area. The mine manager may also be a member of a common interest group.

As in all relationships, clear communication will help the manager to develop mutual confidence with the stakeholder. It is a matter of understanding how the other stakeholders will react in a given situation and allowing them to gain an understanding of the operational business requirements. It is a case of being consistent. As the relationship evolves, mutual trust should be seen as a critical success factor.

It is helpful for a mine manager to be clear in their mind of the motivations, priorities and difficulties involved with each stakeholder to help them to understand their point of view and concerns. Mine managers need to know how to identify key stakeholders for the mining project and define their roles. It is important to establish how committed they are to the mining and to prioritise stakeholder requirements and expectations. The level of engagement with stakeholders may depend on their level of interest in the mine and their level of influence. Stakeholders who have a high level of interest and are extremely influential are key stakeholders. Gaining support from key stakeholders can help you win support for mining activities, and make it more likely they will support future plans, such as proposed mine expansions.

The mine manager should also consider whether the priorities of stakeholders are immediate or long term. For a mine manager, it is the immediate that may take precedence over the important. Stakeholder relationships should never be dealt with on the basis of an immediate issue – they have to be seen as long term. Sometimes, however, the immediate needs to be managed to some extent to prevent the issue from escalating.

The mine manager must also gain an understanding of the particular community within which the project is located. Each community is a product of its history, culture, physical, political and social environments. Whether the view is ‘world’s best practice’ or ‘this is the way we operate elsewhere’, the end point must have community validity.

Some people will exclude themselves from this discussion with the comment that ‘We do things the correct way’. Nothing here is intended as a criticism. It is a case that every manager should question the particular circumstances of their project.

A mining project evolves through broad stages during its life:

- exploration
- planning and permitting

- construction
- operations
- closure.

Therefore, engagement with individual stakeholders will vary with each stage of the project. A mine manager will find that their predecessors (exploration/project/construction manager) have established relationships that were appropriate at that time. It is unwise, however, to assume that these relationships are set in concrete. Circumstances change: employees and board members leave and new ones arrive, projects are sold, companies are taken over, local government officials move on and community issues go in and out of favour. A prudent approach begins with your research – review records of previous negotiations and meetings, not just the outcomes. In summary, one is advised to listen and learn, and not assume or impose on the stakeholders, as it is an evolving environment.

The following broad groups of stakeholders may be seen to be too simplistic – in reality their interests will overlap and some groups will have overtones of others. It can be a valuable exercise, nonetheless, to evaluate the distinguishing features of each group.

4.2 WORKPLACE

4.2.1 Employees

The employees of a mining organisation, particularly those working on site, are the most engaged stakeholders. They may have altered their way of life to align their future with that of the organisation and project. Their training and experience may also have prequalified them for their current role. Their personal, professional, domestic, social and financial future is invested in the project.

It may have once been said that ‘if they don’t like it they can move on’. The reality in these times, however, is that there is a skills shortage and employees need to be retained at all levels. The fly-in, fly-out (FIFO) employee who will change employers by simply changing departure flights at the airport, while real, is not typical. The vast majority of employees are loyal to their employer, even if only for reasons of resistance to change.

Many employees come to an organisation with a skill set that does not fully underpin the role for which they have been selected. The organisation may recognise this and train them, using either internal or third-party-delivered courses. The attainment of such qualifications, adjudicated by an external organisation, is usually important to the employee concerned. The external qualification gives the employee self-confidence based on their own achievement. This commences the formation of a sound, ongoing relationship.

This relationship, promoted and cultivated, is the primary outcome through which the manager can effectively engage with employees. The manager, by their actions and the on-site working environment, can foster the relationship. With professionally qualified employees, this commitment is sometimes replaced with a ‘pay them more’ strategy. This can amount to a lack of understanding of what motivates people. Personal (such as external study or courses), family (bringing a young family to site to see where the parent works), or social (attendance at conferences for networking, or recognition of organisation milestones with off-site events) initiatives are likely to be superior retention initiatives. Mentoring relationships are also an excellent employee development area.

An essential part of effectively managing health and safety at a mine is consultation between employers and employees. Although employee consultation is a legal requirement in the Australian mining industry, it is more importantly a valuable means of improving the employer's decision-making about health and safety matters.

The Western Australian Department of Mines and Petroleum code of practice for health and safety at work¹ contains the following characteristics that should be contained in any system of consultation and communication. The system:

- is enabled by a wide-ranging education and training program
- involves as many people as possible or practical
- is properly representative of any diversity in the workforce
- develops from the experience and expertise of the workforce
- motivates involvement, ownership and commitment
- keeps people and processes up to date
- maintains adequate records of agreement and communications for reference and compliance purposes
- is created through consultation with key stakeholders
- adequately communicates how the consultation process works.

Although there are statutory obligations placed on employers to consult employees and health and safety representatives on health and safety in the workplace, employees also have responsibilities to take care to ensure their own health and safety and those of others affected by their work.

As quoted by the above code of practice for health and safety consultation, there are more informal arrangements for consultation and cooperation between mine managers and employees with respect to health and safety. Examples include:

- making particular health and safety information and performance measures a standing agenda item at workplace meetings, such as staff, team and employee representatives committee meetings
- ensuring safety issues and topics are discussed at toolbox meetings
- implementing email, intranet or electronic bulletin boards for safety bulletins or newsletters to encourage discussion and feedback on relevant issues.

4.2.2 Workplace culture

Workplace culture is a distillation of all the relationships between people (including contractors) on site. The mine manager should take a lead in shaping the workplace culture. The workplace culture is, in effect, a mix of a set of physical assets and organisation values, interacting with procedures and timetables which, in turn, shape the workplace relationships.

Is the workplace culture safe, fair, inclusive and non-threatening? The mine manager will need to be sensitive to complex human relationship issues, such as bullying or sexual harassment, however covert or apparently inconsequential they may appear to be. The mine manager must also consider their own style and behaviours. Are you part of the problem or part of the solution? Attributes that you may see as positive, may be seen by others as aggressive or overbearing, and therefore possibly negative.

1. This code may be downloaded for free from the Department's web site, though the URL may change from time to time.

Are there generational issues? The workplace culture that evolved on a site during exploration and construction may not be acceptable into production/operations. Workplace culture can make the difference between a mediocre operation and a high performing one. Consequently, this is an important participant to the overall stakeholder relations spectrum.

4.2.3 Management

The mine manager is, it may be argued, two stakeholders in one. While being the organisation's primary site leader in forging appropriate stakeholder relationships, he/she is also an employee. They should therefore promote the relationships that they aspire to receive. In many circumstances the mine manager will be controlled by organisation policy or procedures. These policies or procedures may be appropriate, but if a mine manager feels uncomfortable with a specific issue they should take steps to make the changes and improvements that are indicated.

Mine employees may see the mine manager as different, on the basis that:

- the mine manager is the highest paid employee on site
- the mine manager has the ultimate control of the mine site and its employees, ie the authority to hire and fire
- the mine manager conditions and sometimes controls the relationship between the employees and head office
- the mine manager's superior experience and skills may allow them to be more influential.

This should not, however, discourage the manager from the task of forging and maintaining a positive workforce climate.

Other on-site managers (such as divisional section heads) also need to be seen by the mine manager as employees, albeit at a different level. This may be slightly uncomfortable for the mine manager, who works in a collegiate environment with these other managers, respecting their experience and specialist knowledge. It is nonetheless accepted that the mine manager will be seen by external parties as having the overall site responsibility.

Mine managers could foster the concept that each employee on the site is equally important in making the site run safely and productively but that all employees have different roles. This style of leadership can engender pride and loyalty.

A mine manager must have effective consultation and communication with employees. This involves all workers on a mine site so that a greater understanding exists on specific issues that impact the operation of the mine.

When done well by the mine manager, there will be a number of important outcomes for the mining operation. Consultation should lead to an improved performance, particularly when introducing a new policy or initiative. Proper planning and the time spent communicating can minimise subsequent misunderstanding. If the mine manager gives regular and accurate information about the requirements of jobs, such as updated technical instructions, product targets, deadlines and feedback, then there should be an improvement in employees' performance, commitment and decision making.

Mine managers who permit discussion of issues of common interest among the staff and who permit the staff an opportunity to express their views can engender improved management, employee relations and greater mutual trust. In addition, employees are more likely to be enthused if they understand where they fit into the organisation, the role their job plays and are encouraged to make suggestions for improvements and ideas for innovation.

4.2.4 Trade unions

The relationship between organisations and trade unions is often rigid, formalised by laws and organisational procedures. While this is an area where mutual confidence can be developed, it is well worth remembering that the ultimate aims of the trade union and the operation may not be closely aligned. The attitude and priority of the employee or trade union representative may vary depending on the circumstances and environment. Training or empowerment of the union or safety representative can develop a relationship with those employees, without engaging with the more centralised union structure. The mine manager should, however, never carry out negotiations outside of the organisation's industrial relations policy and procedures, as these initiatives, albeit with the best of intentions, can potentially backfire.

4.2.5 Contractors

Contractors on any site should be seen as employees as far as the site relationships are concerned. Companies may distance themselves from such relationships, on the basis that this responsibility has been 'contracted out', but the reality is usually the reverse. The contractor's employees are likely to be intertwined with the organisation's employees, both at work and at a social level. The mine manager is therefore often faced with the difficult task of building a sound relationship, but at the same time exercising care not to usurp the contractor's right to manage its scope of work. The mine manager should work with the contractor's senior site person, with the overall aim of building mutual trust, then mutual confidence, moving always towards goals that are closely aligned so as to achieve optimum business outcomes for both parties.

4.2.6 Corporate or head office

Dealing with the off-site or corporate office may at times be challenging for site managers. It may be that the head office is in a different state or country, and that head office staff may not have the technical background or experience to understand the mine manager's issues. Notwithstanding all the above, head office invariably makes the rules and does so in most cases to achieve compliance and risk management objectives across the entire organisation.

The mine manager can, and should, develop relationships of mutual confidence within the structure of the organisation by achieving targets and complying with organisation procedures. However, by demonstrating leadership and initiative, by going beyond the expected, the mine manager can develop a sound relationship with both direct and indirect contacts within head office, in which both parties become more trusting and effective in their respective roles.

All organisations have communication barriers and 'filters' that mine managers need to negotiate through, as well as dealing with organisation politics and conflict resolution. Regular operational reporting is a powerful method of communicating all aspects of an operation to head office.

4.2.7 Others

Shareholders will rarely engage directly with the mine manager (and when they do visit site, a head office person will often be present in any case). Always plan shareholder site visits/briefings thoroughly with head office well before the visit. If a shareholder contacts the mine manager directly, it is good practice to refer them to head office. All shareholders must have access to the same information. If you new information is given to shareholders that has not

been released via the Australian Stock Exchange (ASX) or equivalent, then the organisation may be in breach of the ASX Listing Rules. This same comment also applies to brokers, analysts or news reporters visiting site.

Non-executive directors hold a unique position. As an employee, the mine manager has to answer their questions fully and directly. However, the mine manager will most probably not have been party to board-level briefings and discussions, and so their point of view may not be exactly in line with what the non-executive directors have been told by the managing director or chief executive officer. After such a briefing, the mine manager should always report back to the managing director, so they are aware of what the non-executive director has been told. Some non-executive directors will nurture mine managers as a good direct source, so it is wise to ensure effective upward communications takes place whenever such exchanges occurs.

State and federal government departments are generally dealt with by head office, as are *native title claimants*, *non-government organisations (NGOs)* and *special interest groups*, such as the Australian Conservation Foundation. None of this head office-sourced engagement should exclude the mine manager, as their local knowledge and point of view will be of value. It is recommended that mine managers are included in at least the internal discussions; however, the impact of these relationships on the organisation makes it essential that external initiatives are generated by head office.

The *media* is usually engaged from head office (except possibly in times of crisis). If the media contacts the mine manager directly it is generally advisable to refer them to head office in the first instance. If head office confirms the mine manager may brief the media, an accurate note of what was said should be kept.

The whole field of stakeholder relationships may often be low in a mine manager's priorities, where getting things done may well be paramount. Stakeholder relationships are not like diesel consumption or drill hole patterns, they are illusive and sometimes ephemeral. But they are more important than the above two examples, because they condition the actions of others, a powerful multiplier of effort.

4.3 DISTRICT AND REGION

Larger companies may have community liaison officers (CLO), whose task is to deal with district and regional stakeholders specifically. While they are important for advice and in gauging the mood and perception of the project's impact in the community, the most important relationship is often that of the mine manager in the eyes of the stakeholders referred to below. This is a natural reaction, not least because the manager is the most authoritative face of the organisation and its business in the region.

4.3.1 Pastoralists/farmers

The vast majority of mine sites are contained within a mining lease granted over leasehold or freehold land. A pastoralist/farmer (hereafter referred to as pastoralist) does have rights over the same land. Negotiations will have already taken place with the pastoralist in the project exploration phase, with outcomes to mitigate the miner's ultimate impact on the pastoralist's rights at the project operations stage. The mine manager should therefore be familiar with these negotiations and the outcomes before engaging with the pastoralist.

For example, it would be well worth checking that whatever was agreed to then is being complied with now. It may well be that what the mine manager sees as a benefit will also be seen as a benefit by the pastoralist. Remember that living in a remote, often challenging environment, where the individual is very self-reliant both work-wise and socially, requires a very particular sort of person.

The pastoralist will often see the mine manager as someone just passing through, only there for a couple of years and even then only on site half the time. The pastoralist may well see the mine as an imposition, not adding to his/her situation and even detracting from it. While the mine manager may think that drilling bores for stock or contracting the pastoralist to do road maintenance as mutual benefits, the pastoralist may just want to be left alone. More significantly, the pastoralist may see the results of mine closure as most important, as they intend to be occupying the land after the project comes to an end. Sharing the mine closure plan with him/her may therefore be of potentially high priority and a positive legacy or benefit is left for the pastoralist.

The construction/development stage in particular has to be examined for its impact on the pastoralist. During development there are likely to be contractors coming to site. They may not be aware or sensitive to agreements the mine manager has made with the pastoralist. Their actions will be seen by the pastoralist as being the mining organisation's responsibility. Site inductions, prestart briefings and the like should therefore make due reference to the impact on neighbours.

Periodic meetings with the pastoralist, whether at the mine or on the station, are worth considering if the pastoralist is favourably disposed to the suggestion.

In general, a common-sense approach needs to be applied when dealing with pastoralists in order to create a positive working relationship between the pastoral and mining industries.

4.3.2 Native title claimants

There may be an indigenous family, clan or other group who claim an affinity with or knowledge of the area surrounding or near the mine. This claim may have been acknowledged or is still to be processed. Establishing a relationship with this group should be done very carefully and it is likely that someone from head office will have responsibility for developing, managing and maintaining the relationship.

In cases where a native title agreement (NTA) exists and is registered, the claimants may have specific rights relating to the mining lease. It is therefore most advisable to clarify the exact nature of these rights by referring back to head office and to become familiar with the details of the NTA as the commitments may well be ongoing and site related.

Be aware that these groups are generally represented in negotiations by a native title service provider. While dealing directly with the group may seem appealing, in the long run it may be inappropriate. Another group of claimants may come forward. The specialist facilitator will in most cases sort out the appropriate group who should be engaged. It may seem opaque, and at times, frustratingly slow, but the process is almost always handled by head office and the specialist facilitator. Every state and territory has a series of procedures and publications on negotiations and processes to be followed in dealing with indigenous groups.

Although native title agreements may have been signed, issues of indigenous heritage sites may arise. Local indigenous people are able to assist with the identification of heritage sites, but they also represent the local community, some of which are potential employees or contractors of the mine.

4.3.3 Shire or town council

Shire or town councillors are usually long-term residents with a lot of local knowledge and history, and extensive local contact networks. As such they can be useful contacts. They are also significant community opinion makers. Councillors are politicians/local government representatives. The general manager is the key person to keep informed of the organisation's activities.

Providing the general manager and mayor with email updates as they are provided to the ASX is an easy method to keep council informed.

Councils should be briefed regularly on the project and its activities. Some councils will want an official meeting briefing, with council employees present. With a whole agenda of business in front or behind them, this may abbreviate the time the mine manager has to form a meaningful relationship with individual councillors at such times. It is therefore suggested that a somewhat longer term approach is adopted, with regular contact at all levels of council. In order to assist in this strategy, it is worth considering what aspects of the monthly operations report the local council would benefit from receiving. In addition, is there a member of the site management with a background that best equips them for this liaison role? The mine manager needs to use the time to show the councillors what benefits the project provides to the community. At the first meeting, either official or casual, it may be useful for the mine manager to introduce him/herself and give a brief outline of their experience, remembering always that the councillors may have different knowledge or experience to that of the organisation. It is recommended that contact with the local council be recorded in the site operations report in sufficient detail for head office to keep abreast of the prevailing exchanges and the climate of cooperation.

Some mines provide six-monthly open days, where buses take council and community people through the mine site. This activity provides a first-hand impression of the mining operation; therefore, it needs to be professionally organised, but it also has the benefit of ensuring the mine workers have some empathy with the community.

4.3.4 Community

By way of prioritising, it may be wise to deal with the relevant council and native title claimants before engaging with the regional community generally. Often the regional council will be pleased to arrange a meeting to engage with the community, and may well provide its own facilities as a meeting venue.

It is also worth the mine manager considering whether they have employees who live in the community, either travelling from their home daily or on a drive-in, drive-out basis. It may be possible to involve them in any proposed community meeting. As a general guideline communities will build trust and respect for any project that adds value to the community as a whole. Reaction and acceptance can become more positive over time. Initial concerns dissipate and are replaced by positive signals conveyed by policies, such as regional employment, use of local contractors, assistance with community projects, use of mine equipment for worthwhile causes and small donations to clubs and organisations.

The local community can have a significant impact with the government approval of a mining operation, particularly if they join forces with national NGOs. Having a community consultation group is becoming a necessity for major projects, particularly if a mine is proposing an expansion.

Mining is often the only economic driver in rural and remote areas of Australia and failure to have a supportive local community will curtail the sustainability of the mine and in turn that of the local economy.

In addition, operations in one region may be approved while in other areas refused, based on political lobbying by influential people in the community. When dealing with the local community it is important to be wary of raising expectations and to be careful to balance out stakeholder influence with their level of interest. Always stay in control, build trust, learn to network in the community and try to understand the community's aspirations and culture.

When dealing with the community it is important to carry out a stakeholder analysis and this involves identification of who the stakeholders are, mapping out their influence and interests and finally understanding the key stakeholders, particularly what financial or emotional interest they have in the mining operation. Is it positive or negative? With this information an action plan can be developed. It should be noted that stakeholders' interests in mining projects are dynamic and iterative. Different stakeholders interact across the mine project life cycle at varying stages and stakeholder analysis will have to be conducted several times over as the mine project progresses in order to modify the action plan and to provide sufficient information to the stakeholders about the impacts of the different stages of development.

4.3.5 Local schools

In a similar strategy to asking the council about a community meeting, there may be merit in offering to talk to the local school teachers and pupils. In any event, it is suggested that engaging with schools should start by being very general, looking for what interests them. First engagements may be talking about local flora, fauna or rocks, maybe out in the countryside, but in any case as part of the organisation's environmental management plan. Often, environmental facts, presented at a school level, help the teacher to introduce science into the classroom.

4.3.6 Regional offices of state government departments

Departments such as mines, environment or water frequently have regional offices, from which site inspections with or without prior advice, may be generated. In cases where an inspection notice is given, it would be advisable to check with head office, in case the inspection is planned to focus on an issue previously raised at a corporate level. Similarly, it is recommended that site managers give head office feedback after such visits.

All states have processes that require regular visits to the mine site by government regulators to inspect the progress of environmental rehabilitation and to discuss the environmental performance and the mine operations plan for the next year. The mine manager and environment personnel play a key role in this activity.

4.3.7 Social networks

Social networks such as Twitter, Facebook and blogging sites such as Hot Copper are an intrinsic part of many peoples' personal lives, to the extent that the line between work and private life can become blurred. As a basic rule the mine manager and the staff should avoid these platforms. Companies are rapidly being forced to adapt to all forms of media convergence and development, and this is just one of many areas where this will continue to evolve. This has had the result that most companies have hastily introduced policies to

manage and control social media in the workplace. Regulators, too, such as the Australian Securities and Investment Commission (ASIC) are examining social media from a public domain and continuous disclosure perspective. As a general guideline, if there is no organisation policy dealing with control of social media then one needs to be developed as soon as practicable. As a default, it is recommended that mine managers disallow use of the organisation's communication hardware and software for the purposes of engaging in any non-work related activity. This ought to include 'blogging' about industry issues in general, where a more proper avenue might well be the home-based personal device.

4.3.8 Dealing with stakeholders on overseas projects

It is quite likely that mine managers will, at some point in their career, find themselves managing an operation in a foreign country. Needless to say, this will introduce a completely new and added dimension of complexity to the role, and is one reason why management of overseas projects tends to be undertaken by more seasoned personnel. As a general rule there will almost certainly be a local administration manager available to guide the mine manager in doing what amounts to be the same things, but arriving at an outcome via a different and sometimes perplexing route.

It is often the case that the mine manager is one of the first foreign expatriates to arrive at the project area. In this case, it is recommended that the entire spectrum of stakeholder relations be addressed within the local country context and adjusted accordingly. In this regard, it is also suggested that a guide for expatriates or similar be drafted in advance of any significant personnel as stakeholder relations can be damaged early on, despite perhaps being entirely non-intentional and expressed with good (or careless) intent.

Further reading

There are numerous articles on stakeholder engagement, covering various aspects of a mine manager's role.

The International Council on Mining and Metals (ICMM) is a body that represents most of the world's largest resource companies. One of the ICMM's very useful activities is to produce a wide range of information and best practice guidelines on almost every mining activity that potentially affects the public or any other stakeholders. All ICMM booklets are available for download free of charge from the library area of their web site.

The ICMM promotes the role of mining in a sustainable future. As an international organisation they acknowledge the need to engage with their stakeholders. Five values are applied to their work and stakeholder interaction and these values equally apply to mine managers. They are:

1. care for the safety, health and well-being of workers, contractors, host communities and the users of the materials we produce
2. respect for people and the environment, ensuring that we are sensitive and responsive to the values of host societies
3. integrity as the basis for engagement with employees, communities, governments and others
4. accountability to do what we say we will do and uphold our commitments
5. collaborating and working with others in an open, transparent and inclusive way as we address the challenges and opportunities we jointly face.

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CHAPTER 5

HUMAN RESOURCES

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5.1 ORGANISATION AND JOB DESIGN

Definitions of organisation and the principles on how to go about organisation are many and varied. These perspectives will often differ from industry to industry, mostly due to the long history of lessons learned. This history in mining is very rich and comparable mines offer tried and proven case studies. Each mining operation will have its own unique environment and internal qualities but case studies offer a start for a critical evaluation. Fine-grain organisation at most mine sites can be expected to vary significantly. From the outset this is a recommended place to start.

Returning to definitions of organisation, there are few perspectives on this subject this author considers more useful than that shown in Figure 5.1.1. This diagram neatly describes what is involved in organisation in systems terms. It considers organisation as a set of overlapping subsystems:

- the environment in which the mine operates
- the goals and objectives of the business unit
- its chosen technology
- the human and social subsystem
- the structural elements
- the roles and task subsystem.

This is a holistic model that suggests change in one area will often affect one or more other (overlapping) parts of the organisation.

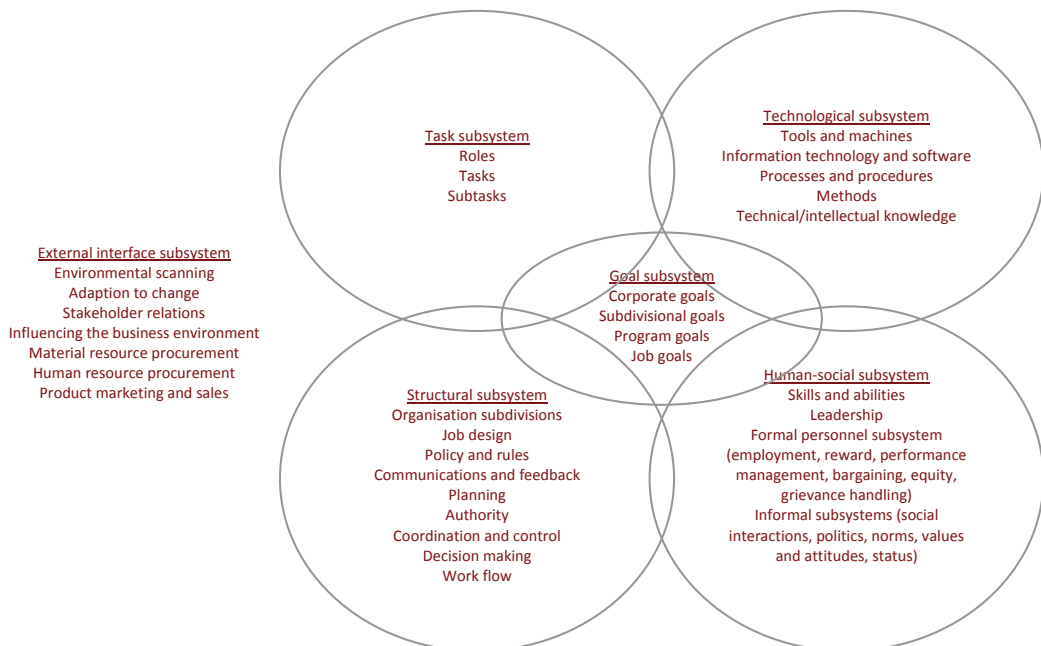


FIG 5.1.1 - Organisations as a system. Adapted from French and Bell Jnr (1978).¹

1. French, W L and Bell, C H, 1999. *Organization Development: Behavioral Science Interventions*, sixth edition, (C) 1999. Reprinted with permission of Pearson Education, Inc, Upper Saddle River, NJ.

5.1.1 Purpose of organisation

The concept of 'organisation' used here is primarily about the division of work. That work, performed either by 'man or machine', is designed to achieve the objectives of the organisation as defined in the strategic and operations plans. Each division within an organisation is a collection of work that has some logical relationship. Necessary interaction between these work elements will be an obvious and key reason for such an assembly. The separation of the divisions is also logical because they can be so without impediment to the organisation. Divisions display sufficient differentiation and independence in an organisation to allow such structures to exist in parallel up to some point where they do require some level of coordination. Both the intensity and frequency of coordination activity can therefore vary.

Hardware strategy is usually a major determinant of the sort of work that must be performed in mining and the major divisions in the organisation. It is generally large scale and expensive and is a hallmark of the high productivity achieved in the Australian industry. This technology generally results in the major functional divisions along the lines of the production sequence.

At the lowest level of organisation there are positions or jobs designed with the same non-human technology components and human components to perform work and produce desired outcomes. There is little difference here to a larger organisational unit apart from scale and type of work role.

Work itself varies in kind from the concrete and highly visible to the more abstract types of work. For example, production and maintenance are very concrete activities, whereas strategic analysis and business planning or stakeholder relations have more of an information or social emphasis. More concrete work is relatively easy to see and measure in physical and behavioural terms. The more abstract work is more difficult to quantify in these same terms. Their inputs, throughputs and outcomes need to be defined differently but they are nonetheless meaningful and observable for organisational purposes. Nonetheless, these differences usually make abstract work a little more complicated to define and calibrate.

5.1.2 The impact of organisation

Organisation has consequences aside from the division of work, which managers must be aware of during design. The systems diagram depicts this well. To name a few, organisation can have an impact on:

- organisation culture and cohesion and levels of internal conflict
- the distribution of power and authority (even justice)
- remuneration correlated to responsibility
- motivation tied to the design of jobs (breadth, challenge, significance)
- the physical proximity of personnel
- formal and informal opportunities for communication (or alienation) and means of social interaction
- alignment and overlap (conflict, opposition) of objectives and operational activity
- work performance at both unit and position levels.

This chapter can only address some of these topics but managers need to remain wary of these downstream effects during design and to remain watchful for any unintended consequences beyond implementation.

5.1.3 Division demands coordination

As already mentioned, along with the division of work comes the need for coordination or management at different levels. The more divisions there are, the more coordination points that necessarily arise. These are the points where the separated work activities need to converge and interact in some necessary way. These activities need to be timed and scaled to optimise the interaction of outputs and/or inputs to combine as new throughput and outputs.

Not all interactions, however, are as constant as a continuous production process. Many are more periodic and coordination between some units need not be as closely monitored or as frequent (for example a drilling campaign). Some can even be described as almost event driven (for example routine maintenance service in a shop). This type of relationship does not require the work activities to be closely connected in an organisation structure.

Close organisational connections do not necessarily mean close physical proximity (unless it is predetermined by the physical production system) but it does always require communication and common information links for consistent feedback and coordination to occur. This distinction is often confused.

5.1.4 The means of performing work and evaluating performance

It is essential to think about an organisation and organisation design in terms of all the means of performing work in the system. Evaluating the performance of such a work system must include the same scope. Strategic plans and objectives generally cascade downward, finding expression as subordinate strategy that is then ‘operationalised’, from level to level down through the structure. There are both human and non-human elements and altering one element usually means affecting others in some related fashion. Non-human elements should be seen as including all forms of technology, from physical hardware and processing systems to the methods and techniques being used by people and the computer software and control processes that are employed.

Design of individual positions or jobs needs to be thought of the same way. All the elements composed of human skills and knowledge and modern technology make up the design of a ‘job’ inside the organisation of the work system. These elements define all the ‘resources’ that are designed to perform the work and achieve the objectives of each position. The concept of the job is discussed in more detail in section 5.2, ‘Organisation Development’.

Evaluating the performance of each position, be it that of a manager managing a division or a solitary operator, should include this holistic perspective, which should ultimately find expression in modern position descriptions (PDs), which should ultimately underpin an organisation design. The PD forms the basis of performance management and it should ensure the modern approach does not focus only upon the employee in this day and age. Performance results are feedback about the design of the jobs and various units and divisions of the overall organisation as it flows upward. This information allows the choices that were made to be assessed.

5.1.5 Coordination as work – the management role

Coordination activity is also ‘work’. It requires the collection of relevant information, analysis, decision making and communication. This will vary in its complexity up through the organisation structure. This work takes up a coordinator’s time, regardless of the level in the hierarchy. This effort needs to be gauged to determine a reasonable workload.

This will affect how ‘flat’ an organisation can remain; that is, how many layers the hierarchy will have. Measuring this workload is more difficult and varies from role to role. Australian mining operations are mature and typically amongst the leanest structures around. They are usually quite flat at five to six levels from top to bottom (excluding the corporate additions). Plenty of practical guidance is already available here and the ability to freely critique the structure of a similar operation should not be passed up.

Practically speaking, a manager or coordinator needs to be able to effectively and efficiently perform the coordinating role. Where the ‘span of control’ is too wide (where the ratio of direct reports too high and/or too much different work activity to align and assimilate) the coordination workload will be too high and organisational performance will suffer. If so, an additional division needs to be contemplated. If this occurs, the coordination role at some other level will gain another element to coordinate.

Rules of thumb abound on the span of control. A maximum of six is often mentioned in the texts and this could be used as starting point for further critical evaluation. At lower levels of supervision of basic operator roles a ratio as high as ten can be quite feasible for simpler roles and well understood work. One can imagine, however, having six highly interdependent and complex work functions reporting to them that are collectively not well understood (technically uncertain), involve high process variance and are challenging to control. These functions would therefore require close and continuous monitoring and coordination. This role would be hard work compared with managing several unrelated support services and two closely related work functions connected in a predictable and very stable work sequence. These examples stress some of the factors to consider on top of the history on display elsewhere in the industry.

5.1.6 Advancing coordination technology

Coordination technology is a significant new element to consider in a contemporary organisation. These highly integrated monitoring, processing and control technologies rely on sophisticated surveillance, communications networks and computer systems. They can also be located long distances from the processes they are coordinating. Ultimately these technologies may progressively remove the human element from the organisation of the work system. Lower level operators will be removed (ie unstaffed operations). Presently such systems still require human coordinators working alongside higher level operators of the new technology.

5.1.7 Some more practical issues guiding organisation

Turning now to a more practical posture, there are a set of familiar defining questions that are useful in general organisation and job design.

The basic questions to ask to aid design are discussed below.

WHAT WORK NEEDS TO BE PERFORMED AT THIS OPERATION?

Guidance from the core production strategies selected for the scope of the operation and the organisation case studies available from other similar operations are assumed here. The first level divisions are probably the easiest to determine in many respects. For greenfield sites such data is available in conventional feasibility studies and these reports should be utilised as the original business justification approved by the board. At brownfield sites the organisation will of course exist, but parts presumably require some revision due to performance problems.

So, given the selected technology, what are the positions that need to exist for the employment of personnel to perform specific roles? Job design needs to consider the scope of the work that will be expected of an employee in relation to the availability of personnel in the labour market with the skills and knowledge necessary to perform these roles. If a job is designed with a scope wider than the breadth of skills typically available in a conventional occupation, it will be difficult to recruit a person who is not otherwise lacking in some area.

While this will be challenging for the right person recruited into such a wide role, coaching and training will be needed and that must be factored in. On the other hand, if the scope of a job is designed too narrowly to allow the utilisation of all of the skills usually possessed in the occupation (ie skill variety, completeness) or the position does not exert the same influence in the organisation (ie autonomy, significance) it will be less attractive. Either case can affect employee job satisfaction and performance and attraction and retention. This will influence long-term organisational effectiveness.

Position descriptions, as mentioned, capture job design and need to specify the collective role responsibilities and key work outcomes that are required for the positions to align with and converge on unit and divisional outcomes (in a manner of speaking). Importantly, the relationships with other positions need to be specified to ensure the expected interactions are defined and the coordination needs are highlighted.

CAN WE DO IT BETTER THAN A MINING SERVICES PROVIDER?

This question is really about *outsourcing*, which is a special consideration of what work can be contracted out to external parties. This decision needs to include a joint commercial, operational and industrial relations justification.

There are a range of drivers. Scale is a common determinant of outsourcing decisions and where support services, for example, are too small to justify an internal structure (ie IT, communications, recruitment) this is often the case. At another level, strategic advisory services are difficult to justify internally when the occasional requirement makes external consulting services a far cheaper option and they can often be a higher calibre of expertise.

Where skills are rare and expensive they are also usually difficult to retain at a mine site. Sometimes, in large organisations, the corporate function will provide high-level expertise across the organisation that no one mine site could justify.

Supplier availability and responsiveness are other drivers that residential operations may enjoy, but not commute operations. Emergency and relief labour falls into this category along with shutdown services.

Larger-scale cases emanate from project financing decisions. For example, build-own-operate contracts, where the site-based assets, their operation and labour are all outsourced. Nowadays this includes complete processing facilities, not only the conventional mobile mining fleets or vendor maintenance services.

HOW DOES THE WORK NEED TO BE ARRANGED?

Guidance for this question has been provided above. Relationships between the work as it is divided between the positions, senior or junior, will define several logical arrangements in most cases. There will always be many competing solutions to this type of design so pragmatism argues for starting with a flat structure and piecing positions together beneath the required coordination points with spans of control and coordination points that are logical across the work system being organised.

WHERE DOES THE WORK ACTIVITY NEED TO BE LOCATED?

This question concerns the geographic proximity of the work and all resources connected with it. It requires consideration of effectiveness, efficiency and the overall cost of delivering the work. In particular:

- All labour costs need to be considered amongst different alternatives in terms of direct and overhead costs. Office, residential accommodation (town or village) and personnel logistics costs all need to be included. These are significant recurrent costs.
- Personnel attraction and retention dynamics of each site need to be considered. Personnel turnover rates progressively increase from metropolitan sites, regional residential sites and regional commute sites. Location will affect vacancy rates and vacancy durations. This impacts directly on the labour coverage of jobs, continuity of the work and labour costs.
- The Australian mining industry is also divided with numbers of commute mine sites now dominating residential sites by as much as 2:1. This can be assumed to describe the de facto accommodation preferences in the labour market amongst prospective employees. It also provides employees with opportunities for lifestyle change. Locating a position at one or other of these sites will effectively halve the size of the labour market that may be attracted to a job. Mixed residential and commute sites enjoy 100 per cent labour market exposure in this respect.
- Scale is again an important driver to consider here. If workloads are too small to support a site role it will be folly to do so. The services are better conceived either centrally from a head office or shared services function (or even outsourced). Otherwise incumbents will become bored or distracted by other site activities and/or become prone to turnover on a regular basis due to underutilisation.

There are some trends in the industry aimed at locating more personnel in metropolitan offices as opposed to a remote site. This typically includes regular monthly site visits by these personnel to maintain site-based relationships and their direct site knowledge. It also requires a disciplined reporting structure. That is, a culture where unauthorised influence and use of resources by parties outside the structure and formal channels is not tolerated. When it occurs, it will simply erode the responsiveness of a city-based service to a site-based client, for example.

WHEN DOES THIS WORK ACTIVITY NEED TO BE PERFORMED?

This question is about the labour coverage requirements of each role around the clock, in other words: working hours and roster arrangements. Work coverage alternatives are endless but some major considerations are:

- continuous coverage 24 hours a day, 365 days per year (24/7)
- non-continuous day coverage, 365 days per year (12/7, 2 × 8/7)
- weekday coverage, the conventional five days per week or nine-day fortnight.

Shift durations are commonly ten to 12 hours at most sites today, with office roles nominally eight to ten hours, usually at the shorter end at residential sites.

Overlap of personnel during shift changes and handovers is an important communication and coordination consideration for the organisation if it can be achieved. Complementary systems include shift logs, email use (note this medium requires discipline and focused application) and shift start briefings by supervisors.

Time is also an organisational issue that can influence job design and personnel numbers:

- When work can be safely performed is a conventional risk assessment question. Night shift work will often differ from the same role performed during day shift. It is common practice to remove the risk (eg some open pit work requires good vision and therefore light). There is also more complicated work requiring concerted periods of concentration that might be better avoided if there is a critical risk of fatigue affecting performance.
- Working hours and rosters will have a direct effect on personnel numbers, carrying with it logistical implications for personnel accommodation and transport. Assuming 12-hour shifts
 - Even time continuous rosters will require four-crews. For each job requiring 24/7 coverage four personnel will be needed per job, plus additional resources for leave and any other coverage.
 - The 2:1 ratio rosters (eg 14/7) require three-crews. As above, each job will require three personnel per job for 24/7 cover plus additions for leave and other coverage.

5.1.8 Personnel logistics – accommodation and transport

Personnel logistics issues at commute sites deserve some emphasis to ensure they are not neglected as key organisational issues. For human resources, they are just as important as the supply of any other resources to ensure their availability to meet operational demand. Done poorly, personnel logistics will cause significant lost productive time that is being paid for without any return for the organisation.

For personnel accommodation at commute villages, personnel levels affect room numbers, which is in turn affected by room allocation policy. Commute rooms are very expensive today so policy such as ‘motelling’, in its various forms, has become commonplace. Dedicated rooms (ie left vacant during an employee’s R&R breaks) are today becoming less common (other than for senior ranks). This trend has been accompanied by far more elaborate room facilities, including room servicing and hygiene standards being applied by catering contractors to facilitate the motel mode.

Commute transport is generally easiest to plan when there is a choice of public open flights and hardest when private charter flights need to be used. Charter flights are a finite resource and should be optimised to ensure cost efficiency and maximise seat utilisation.

The number of discrete rosters can also challenge this objective. It is without doubt best to keep roster numbers to a minimum for efficient planning and to maintain some semblance of ‘human comprehension’. Rosters are difficult for many to understand. This is not to say the roster/logistics issue becomes the ‘tail wagging the dog’. That would be an organisational error, but some balance is needed. There are sites in Australia with over 30 different rosters and reviews have been extremely complex and difficult affairs.

Shutdowns may require large numbers of external personnel from outsourced service providers to reside on site for short periods. This can be a major challenge when working within existing resources.

5.1.9 Some tales and cautions

The following points are used to round out this section with some cautions concerning some ‘old chestnuts’ that are contentious issues and often cause debates.

MAINTENANCE ORGANISATION

Different organisations have placed the maintenance function and the production function in the same division. In this case maintenance is the responsibility of the function manager concerned. Many see this as the correct alignment of interdependent activities aimed at a common production objective, which results in a more harmonious operation.

Others argue that production will have priority over maintenance and asset management will suffer. The latter may be a risk; however, adopting asset management standards and monitoring performance against these standards is an easy solution to any threat of long-term asset abuse and failure.

Others have nonetheless placed the maintenance function separate from the production function. Most often it is placed in an engineering function. Organisationally, this gives maintenance the same status and 'power' as the functions it supports. The result is that maintenance can make decisions independently of production about taking an asset out of service or a shutdown. Conflicting plans will require coordination between production and maintenance engineering and this will gravitate to the next level, say an operations manager. Caution is recommended here to avoid decision making becoming necessary at this level.

SILOS AND TERRITORIALITY

Historically, the mining industry has suffered from the symptoms of the 'them and us' syndrome, in terms of on-site and off-site activities. This is essentially about power and trust in the relationships established by an organisation. This has been most obvious when it comes to delivering indirect support services to the operations. There has been a tendency as a result for regional mine organisation structures to include all these functions and for some to also exist off-site in head offices. The result is redundancy and overlapping responsibilities. This situation is much easier to fashion in these functions than in more 'concrete' functions described earlier. Over-staffing is a symptom.

Arguments in support of 'site silos' are as plentiful and varied as the arguments for 'hubs' or service centres in head offices. The issue reduces itself to site dissatisfaction or lack of trust in the responsiveness and level of service that can be provided from central offices (as already touched on). This is a risk that needs to be controlled.

Part of the reason for this perception lies with the 'tyranny of distance'. Distance can influence whether ready access to support service personnel can occur or not for face-to-face communication. Both affect site knowledge of head office activity and progress on site work. Another reason rests with competing priorities that affect head office service centre personnel and their delivery of site services. This split role is not a workable combination and is usually avoided by dedicated service centre managers with clear client priorities.

AUTHORITY, RESPONSIBILITY AND ACCOUNTABILITY

An old adage goes something like 'there can be no responsibility where there is no authority'. This refers to the formal span of control over not only the direct reports in the organisation structure but also decision making across policy subject matters. Service functions, such as accounting and finance, human resources and industrial relations, information technology, contracts, procurement, insurance, logistics, etc, are now commonly and correctly considered as support services to the operations functions. They provide expert advice and services to the operations but should never assume or be given authority for making decisions directly affecting the performance of operational areas. Those responsible for the operations accept

the input from support services when considering their decisions. Making those decisions is their responsibility, as is their accountability for the operational consequences. Support services are only responsible for the quality of their advice, not those decisions made by others they support.

5.2 ORGANISATION DEVELOPMENT

Organisations may be thought of in the following terms:

- social entities
- goal directed
- designed as deliberately organised and coordinated activity systems
- linked to the external environment.

As such, the work of managers is more complicated than just making great technical decisions about the productive processes. This is because their decisions are usually enacted upon by other people in the organisation who have free will, ideas and expectations of their own. For managers to make decisions that are acted on by others in the way they mean them to, managers need to develop some understanding of sociology and psychology as well as the organisation's goals, design and structure and the external environment in which the organisation operates.

Managers who are able to get their work done through the effort of others are often referred to as leaders. In simple terms, managers define purpose and perform work to ensure the operation of the business processes; leaders have voluntary followers who take direction from their leader to willingly exercise their productive efforts to operate and improve the business processes for the benefit of the organisation.

All managers have a set of theories or philosophies upon which they carry out their work of managing the people and processes under their authority. Many of these personal theories are based on their technical discipline and are often underpinned by recognised professional qualifications. Other theories are learned through previous personal experience or observed practice of others, such as the shared stories and wisdom of parents, coaches and mentors who contribute to the behaviours they apply in performing their work. There are also the theories and directions determined by the organisation they work in that are required to be applied, usually in regard to code of conduct, management behaviour and authority and desired organisation culture that underpin the productive processes.

As managers go about their work they attempt to put all of these theories into practice by making decisions, assigning tasks, communicating with and influencing others. In essence, this is what organisation development is all about – managers turning the full suite of personal and organisational theories into action through the efforts of others.

It is no wonder that organisation development is seen as a priority for organisations seeking to apply contemporary human resource practices, especially where employee engagement is sought as the foundation of the desired culture. The aim in this type of culture is to get all employees to willingly exercise their discretionary effort to consistently perform their jobs very well and work to improve their job performance for the benefit of the organisation. All human beings have free choice in their lives and managers can only influence others and not control them, which makes the work of motivating and predicting the behaviour of employees in performing their work, vastly more complex.

Figure 5.2.1 attempts to give a pictorial view of the intended change process to improve organisation performance. Not all organisations fall neatly into the first group on the left,



FIG 5.2.1 - The influence of organisation development (Senge, 1990).

but it is the work of managers to ensure they lead those who report to them and others they influence and continually improve business benefit through their behaviours and decisions. The steps in improvement occur due to the effective, consistent and continued efforts of the organisation's leaders using their knowledge and influence and the available knowledge and experience of the employees they lead.

This handbook section is aimed at providing managers with a brief overview of organisation development and a basic understanding of the effect of their behaviour and decision making in achieving sustainable personal and business success. The sections in the chapter cover some of the fundamentals of organisation development, including organisation structure, staffing, values and culture and policies and procedures.

5.2.1 Organisation structure

An organisation exists to attain the goals shared by its members and these goals are achieved through the members performing their tasks effectively. An organisational structure determines formal power and authority, reporting relationships and roles within the organisation.

When many of us think of an organisation structure a bunch of boxes and connecting lines automatically comes to mind. What we are thinking about is the organisation chart, which is a diagrammatical representation of the actual structure of people in roles that are directed by managers to make the organisation work and effectively produce the output from its operating processes.

Conventionally, each of the boxes on an organisation chart represents a role or position in the organisation and the lines that connect the boxes show there is a reporting relationship that exists between linked roles. Roles are shown on separate rows on the chart in relation to each other when they perform work at a different level, to separate them from the roles that report to them, eg supervisory roles are usually separated vertically from the roles that report to them on organisation charts.

Similarly, roles are generally grouped together according to the type of work the incumbents perform for the organisation. Groupings are usually based on whether the roles are involved in the operational activities of the organisation or service or support functions. These usually appear separated horizontally on an organisation chart.

Commonly used organisation structures show the roles with higher levels of accountability occurring towards the top of the structure and at each individual horizontal level appearing

vertically down a chart there are common levels of accountability for the tasks inherent within each role. This type of organisation structure is referred to as an ‘accountability hierarchy’, where the organisation structure is based on the levels of accountability (distributed vertically) and grouping of functions (distributed horizontally) of the roles that occur within it.

There are a number of philosophies and diagrammatical representations for organisation charts, one of these being matrix structures, but these are less often used in practice and require greater complexity in development and explanation for employees at all levels, and these will not be investigated in this chapter.

An accountability hierarchy is based on the work, authority and accountability of the roles that appear in it. An example of an accountability hierarchy based organisation structure is shown in Figure 5.2.2.

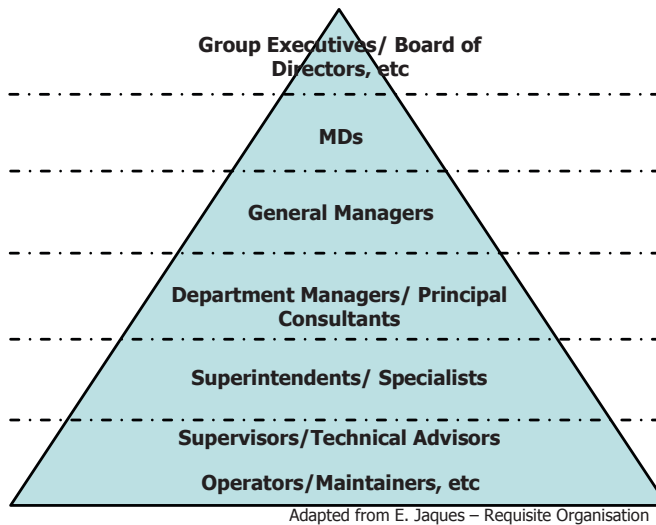


FIG 5.2.2 - Accountability hierarchy organisation structure (Jaques, 1989).

Irrespective of any manager’s philosophy as to whether the triangle should appear upside down on its point or rest on its base, the relativity of positions, their separation into authority levels and grouping into functions is still indicative of an accountability hierarchy.

As a manager you need to keep in mind that an organisation structure is a visual representation of the roles that are required to occur in the organisation and the people who are incumbents in those roles. The structure itself is only indicative of the work these people are required to perform and the direct reporting relationships they have with their immediate supervisor.

Once the organisation has been designed to achieve safe, cost-effective, quality output the real work is the essence of organisation development; using the term introduced earlier in this chapter, the design is only as good as the ability of the managers to turn this design theory into day-to-day practice through the role incumbents.

As Figure 5.2.3 shows, unless you do the work in a way that takes the range of theories referred to earlier in the chapter and turn them into action through the human and physical resources available there will not be any productive output from your work. Similarly, unless you have a set of well-thought-out theories aligned with the organisation’s objectives to apply through these resources the organisation will be poorly directed and not able to consistently achieve them, except through luck.

FIG 5.2.3 - Theory and practice.

The organisation is structured so roles that occur at any level carry out work under the direction of, and report to, roles at the next higher level. Further, there are more roles at the lower levels of the structure, reducing in the number of roles at any level as you go higher up the structure. This is mainly because roles lower in the structure are employed in producing the output for the organisation with roles that provide leadership and direction shown immediately above.

It is a necessary part of the manager's work to review the organisation structure at least annually to ensure it continues to be most appropriate to achieve the organisation's purpose into the future. Performing a review must not presuppose a change is needed – 'if it ain't broke, don't fix it', but don't fall into the trap that it doesn't need reviewing either. Many organisations fall into the trap of making repeated changes in organisation structure, with little benefit to the organisation. This often occurs because changes in structure are relatively easy to execute while creating the impression that something substantial is happening when it really is only an impression.

Repeated changes create instability with employees at all levels and if the change does not result in real benefits to the organisation a drop in performance and likelihood of an increase in employee turnover will result in significant damage to the bottom line. Also, the rhetoric used by managers to explain the reason for the change will be seen as dishonest by followers, thereby reducing the effective influence of the managers causing negativity in the organisation's culture. More powerful and positive change happens when there are clear design objectives driven by a new business strategy or forces in the market that require a different approach to organising resources that are then effectively applied through the people who perform the work in any revised structure.

5.2.2 Staffing

The organisation structure places roles in relation to each other; the next stage is about clarifying the work to be performed in each role and the working relationships that are to be developed and maintained to ensure the role incumbents can be successful in their roles for the benefit of the organisation.

The organisation structure is a picture of the theory for the organisation and the subject of staffing looks at determining the activities that are grouped together to form the work of each of the roles into which individuals can be appointed through recruitment and selection. Staffing is also used to confirm in more detail whether the positioning and relativities of roles in the organisation structure are appropriate to sustainably achieve the purpose of the organisation. Therefore, staffing is the first stage on the pathway of translating organisation structure theory into action before including employees to do the work.

The aim of selection and recruitment is the process of identifying the most appropriate individual for appointment to a clearly defined role so they can provide value in terms of output for the organisation. Recruitment is covered in a later section of this chapter, but its primary purpose is to achieve the manager's vision of correct job/person fit – staffing is aimed at determining the skills, knowledge and abilities required for an individual to be successful in a role.

What is a role? A role is a position in an organisational structure with specified work functions, some general accountabilities and a current basket of one or more assigned tasks and projects. A role is performed by an incumbent who can apply technical and practical abilities supported by the qualifications, competencies, capabilities, experience and cultural fit necessary to contribute to the sustainable success of the organisation in that specific role.

Different types of roles are required to ensure organisations achieve their organisation's objectives and continue to do so over time. Roles are usually classified according to their relationship with the production process and the type of work performed in them to achieve the required output. Roles are often classified on the basis of three core functions for the effective operation of the organisation and are frequently referred to as either operating, service or support roles.

Operating roles are those directly involved in the process of producing the output of the organisation, resulting in it receiving payment from customers. These roles include those of operators of the plant and equipment that change the process inputs into saleable outputs. These roles, and those accountable for leading and managing them, exist directly to deliver profit to the organisation.

Service roles are those which perform work for operating and other roles for the organisation to function in a sustainable manner. These include supply (which provides raw materials and other consumables), human resources (including recruitment and payroll), finance (manage company funds and payment of contractors, suppliers, etc) and others. Those who work in service roles perform work to assist and enable those in operating roles to control production processes successfully in a sustainable way.

Service roles carry out work mainly to sustain the operation in the current term, though they have implications over the medium term arising from the performance of their work. For example, when the recruitment function performs its work it is usually seeking to provide new employees to fill roles in the organisation where there are current or near-future vacancies. Other service roles include maintenance, where the work is done to ensure the reliability and availability of the plant and equipment for use in production processes, as well as breakdown recovery.

Support roles are those where the function is to enable operating roles to be successful and improve in meeting the organisation's purpose and obligations in the mid to long term. These include roles such as development, process and other engineering disciplines, which seek to improve the operating process over time. Others include specialists in occupational health and safety, environment, employee relations, etc.

All roles within the organisation structure are created to perform tasks and each role usually has elements of three general work components – people work, programming work and technical work. These elements occur in almost all roles, including operations, service and support roles, with the amount of each varying dependent on the purpose and level of the role.

The *people* component of a role is related to the work of interacting with, following, leading and managing others. For managers this work is structured around setting the context and

purpose for employees in subordinate roles, assigning clear and measurable tasks, reviewing the performance of these tasks, providing specific individual feedback to employees about their performance for the purpose of recognition and improving performance in the future and rewarding work performance that results in benefit for the organisation. The proportion of roles related to the people component tends to increase for roles higher in the structure.

The *programming* component of a role refers to the work of planning and scheduling each individual's work activities and ensuring programming of the work of others in subordinate roles is carried out in accordance with the needs of the organisation.

The *technical* component of a role comprises aspects of work that involve elements of some discipline or profession where the skills, knowledge and abilities of employees are applied to achieve either a direct or indirect transformation of raw materials or intermediate products into final saleable output from the organisation.

All organisation roles have at least some aspect of each of the role components of people, programming and technical. Even if no positions report to a role, there is still the need to work with others in the organisation and be effective in interactions with others for the benefit of the organisation.

For incumbents in all roles to be able to perform their work they must be granted and be allowed to exercise specific authorities with respect to making and implementing decisions. *Authority* is the power to make decisions and act, which can be legitimately used by a person in their role when performing work. Legitimate authority is vested in the position and not the person in the position and often referred to as 'role-vested authority' since it forms an integral part of the individual's role in the organisation.

Authority means that a person can consume and utilise resources in the form of materials, technology, money, people's time and effort, etc for the purpose of achieving the objectives of the organisation related with the tasks assigned to their role.

Another form that authority takes is 'personally-earned authority'. Personally-earned authority is the authority earned by an individual in their role due to the demonstrated actions and practices the individual displays in carrying out the work of their role. This is the authority or respect granted to the individual by the team members and others in the organisation that has been earned by their actions and decisions. Personally-earned authority does not come with the appointment to a role; it must be earned by each individual through work performance, interacting with others and generally being able to consistently perform their work and enable others to be successful in theirs.

The balance that is applied with respect to the authorities that are allotted to role incumbents is that they are held accountable for the outcomes and results from their decisions and for ensuring they make all required decisions within their authority and not leave the decision-making to others. With the authority comes the accountability to apply it in making the required decisions for the benefit of the organisation; it is not acceptable to withdraw from making the decisions required by the role.

5.2.3 Values and culture

Most organisations identify a set of values that are developed and communicated. These values are often used for all members of the organisation to base their behaviours on and communicated in a values statement, code of conduct or similar document and described as forming the basis of the desired organisation culture. Values are an inherent element of humanity and organisational values should be attributed to the people who work in and shape the way the organisation deals with people through its operation and decisions.

The types of *values* that are communicated by organisations often include the following:

- integrity
- trust
- honesty
- mutual respect
- openness
- fairness
- appoint the best people to jobs, etc.

The intention of communicating the organisation's values to employees, potential employees and other stakeholders, including the community, is to attract and retain employees, customers, suppliers and to create goodwill in the communities in which the organisation operates and deals. As such, the values become linked to the reputation of the organisation and the people who work within it. The organisation is then evaluated on the basis of the decisions made within it with respect to each of these stakeholders through the lens of these 'values'; and the organisation is often praised or criticised dependent on the perception of those affected by its operations and those observing it.

What is essential to understand is that a *culture* is formed when people share assumptions about whether behaviours demonstrate positive or negative values. It is critical for a leader to be able to predict people's behaviour and their likely response to situations. The leader must be aware of how people are likely to react and then be prepared for such reactions.

The leader should be aware of various cultures that exist in their work unit as well as being accountable for creating a desired culture within the organisation – one where the resulting actions are productive.

The meaning and definition of *symbols* is an essential part of leadership. For a leader, almost all of his or her behaviour will be taken as a symbol demonstrating underlying values. Manipulating symbols and behaviour is not easy and cannot make a good leader in itself; consistency is essential. There are many symbols in organisations ranging from types, quality and colour of work clothing and articles to allocated car parking spaces, etc.

Systems are critical because they are the equivalent of the non-verbal behaviour of the organisation. If there is a contradiction between what an organisation says (ie its mission, vision statements and policies) and what the organisation does (ie the way in which the systems are designed and implemented) it is the latter that people will believe.

Systems are the ways in which an organisation operates and an organisation's systems have embedded within them values which will be interpreted through the assumptions of the people who are subject to them. Many systems are concerned with managing people, such as recruitment, selection, induction, promotion, discipline, remuneration, task setting, planning, retirement and redundancy, though systems that appear to be less directly associated with managing people like computer systems, information systems, financial systems, and so on, still have an impact on assumptions.

Everyone in the organisation will have a view concerning the symbols and systems and they will be explicitly or implicitly rated against the espoused organisation values. If there seems to be a difference between the leaders' behaviour, the systems and/or symbols and the organisation's espoused vision and values the result will be an organisation culture that is negative and not aligned with the intended vision.

5.2.4 Policies and procedures

Policies and procedures are documents, whether stored on paper or electronically, that describe an organisation's mode for operation. They are often initiated because of some external requirement, such as environmental compliance or other governmental regulations and are usually essential to the organisation's quality systems. These primarily exist to provide a framework for consistency, transparency, accountability and quality of management.

All organisations have policies and procedures that guide how decisions are made and how the work is done. Well-written policies and procedures increase organisational accountability and transparency and are fundamental to quality assurance and quality improvement programs.

Even where policies and procedures are not written down, they exist, guiding the decisions and determining how people who interact with the organisation are treated. The problem with unwritten policies and procedures is that they are not subject to the usual organisational reviews and accountability processes. In the absence of written policies and procedures, unacceptably different approaches that make the organisation inconsistent and inefficient can develop.

There are four very basic reasons that necessitate writing policies and procedures:

1. operational needs – policies and procedures ensure fundamental organisational processes are performed in a consistent way that meets the organisation's needs
2. risk management – established policies and procedures are needed to manage risk
3. continuous improvement and quality – procedures can be used to improve processes by implementing and communicating a standardised approach to internal business and operating practices
4. compliance – well-defined and documented processes (ie procedures, training materials) along with records that demonstrate process capability can demonstrate an effective internal control system compliant with regulations and standards.

Are policies and procedures the same thing? No, they are not. Policies and procedures apply to different levels of the organisation's documentation, primarily existing to communicate and manage its key determinants of quality, culture and compliance.

Policies are statements of intent covering principles and practices dealing with the ongoing management and administration of the organisation. Policies act as a guiding frame of reference for how the organisation deals with everything from its day-to-day and longer-term operational problems or how to respond to requirements to comply with legislation, regulation and codes of practice.

Procedures explain how to perform tasks and duties. A procedure needs to specify who in the organisation is accountable for particular tasks and activities, and how they should carry out their duties and to what standard. Procedures have many names including, but not limited to, business procedures, standard procedures or standard operating procedures (SOP) and work instructions or standard work instructions (SWI), etc.

What then are *instructions*? They are:

- task- or practice-specific directions
- the 'rules' by which the organisation operates.

Like procedures, work or task instructions tell people what will be done, when, by whom and to what standard. Task instructions relate to particular task(s) associated with a given procedure. For example, an organisation may have in place a staff appointment procedure

that addresses various issues and the roles of staff; one component of the appointment procedure might involve public advertisement. Rather than clutter the procedure with directions on how to run an advertisement, a work or task instruction would be used by the staff member responsible for placing the advertisement.

The links between policies, procedures and instructions are as follows:

- policies are the founding principles
- procedures are the recipe for how things get done
- instructions flow from policies and procedures, giving more details on how to do the work.

Policies, procedures and instructions exist in all organisations to a greater or lesser extent. The key to success for any organisation is not a building, plant or site; or even a set of policies, procedures and instructions. Organisations are made up of people and their relationships with one another. It is the sum of all its parts underpinned by the people and their interactions with each other, the plant and processes they are provided to work with and the environment within which they work that determines the success of the organisation over time.

It is essential that the work of a manager is to get the organisation structure right with the correct requirements for staffing it and then ensure there are clear policies, procedures and instructions for the people who work in the organisation to follow. The real work is that of leadership by setting the example in behaviour and decision making. Leaders who carry out their work by demonstrating and reinforcing the values and standards will attain a voluntary following of people who will apply their discretionary efforts to achieve quality work output, contributing to a consistent benefit for the organisation.

5.3 RECRUITMENT

5.3.1 Purpose of recruitment

The purpose of a recruitment system is to identify, attract, assess and engage human talent that is aligned with the corporate goals and culture of an organisation. Recruitment methodology has changed dramatically in recent years as a result of changes to workforce mobility as well as communication technology generally.

Effective recruitment programs will:

- no longer be reactive only, but must be proactive in many ways
- target specific technical skills required within an organisation's workforce
- ensure good cultural alignment between individuals and organisations
- include a robust process that treats candidates professionally at all times.

Reactive recruitment activities include things such as media advertising only, waiting for a specific vacancy to occur and responding to unsolicited applications.

Proactive recruitment activities include things such as permanently open vacancies, ongoing business branding activities, targeted search work and maintaining contact with a prospective candidate pool.

Technical skills required are relatively easy to identify through organisational development and job design processes.

Recruiting for cultural alignment includes assessing the culture of an organisation by using surveys of existing staff and then assessing potential new employees for their fit against these values and attitudes.

These surveys can be carried out informally and recruited for informally, or they can be carried out by formal external consulting processes.

5.3.2 Recruitment strategy

Assuming that a thorough understanding of an organisation's technical and cultural requirements has been carried out, then the first thing to be considered when planning a recruitment program is the scale and scope of the program.

Key questions include whether a complete new workforce is being sought or whether positions are being recruited to fit within an existing workforce.

As recruitment often employs various forms of marketing and market research, it can be extremely useful to assess what previous recent recruitment activity has been carried out, be that successfully or unsuccessfully, for similar positions. Assessing what worked and what didn't work previously will usually save considerable time and effort.

Lastly, the key factor determining a recruitment strategy is whether the activity is aimed at filling known vacancies that exist now, or whether the recruitment activity is aimed at creating a pipeline of potential candidates that might be suitable for and interested in potential future vacancies. With this in mind, sections 5.3.3 and 5.3.4 distinguish between broadly proactive and broadly reactive recruitment activities.

5.3.3 Proactive recruitment

Proactive recruitment can be defined as activities that are carried out, not necessarily when there is an obvious and immediate vacancy. The reason for employing such activities would be to effectively 'brand' or 'position' an organisation in the minds of potential candidates. At times these programs may go further and encourage those potential candidates to register their interest in the event that a position were to become available.

The goal of such strategies would be to have potential candidates partially screened and aware of the organisation, thereby reducing the time between identifying a specific vacancy and when that vacancy is filled.

A lot of these proactive activities could be classified as essentially marketing and market research type activities. Proactive recruitment could include things like:

- the placement of branding advertisements into trade publications
- an organisation's attendance at industry conferences
- an organisation's attendance at career fairs
- the placement of regular branding advertisements into the 'jobs wanted' sections of web sites and print media and job boards
- referral programs
- executive search activities
- sponsorship of sporting or community events
- interaction with candidate communities through social media.

One of the biggest benefits of proactive recruitment is that it spans a much longer time frame, uses a wider range of attraction strategies and as a result should inevitably expose an organisation to a much larger group of potential candidates. If the assessment processes

are managed properly, this should improve the average quality (in terms of technical and cultural fit) of the candidates eventually employed.

5.3.4 Reactive recruitment

Reactive recruitment can be defined as activities that are carried out when an obvious and immediate vacancy has been identified.

Reactive recruitment should use as many attraction devices as possible, while obviously being mindful of the time constraints that exist. Some of the activities listed under proactive recruitment above may also be able to be utilised (time permitting) but could also include things like:

- the placement of advertisements into newspapers
- the placement of advertisements into daily email newsletters
- the placement of advertisements onto industry specific internet job boards
- engaging external recruitment and search consultants.

Given that under this scenario there is often more pressure to fill a vacancy, it is very important not to rely upon one attraction device only. Using a single attraction device, under time pressure, will inevitably result in the identification of a very small number of (or perhaps no) suitable candidates. This has the effect of reducing the average quality (in terms of technical and cultural fit) of the candidates eventually employed.

REACTIVE VERSUS PROACTIVE RECRUITMENT

The next sections offer discussion about the various elements of a recruitment program. When implementing these various elements it will be important, amongst other things, to be mindful of the extent to which your recruitment program is able to use proactive initiatives or whether you only have the opportunity to enact reactive initiatives. This will differ from one recruitment project to another.

The sections following have not gone into a detailed discussion about executive search techniques specifically, as these are specialised activities that inevitably require the engagement of external search consultants. Few organisations have dedicated internal executive search (proactive) teams.

Suffice to say that proactive search assignments should be considered for:

- particularly hard to fill, or highly specialised vacancies
- particularly senior vacancies
- where a board or senior management committee is required to benchmark their internal candidates against the broader candidate market
- where the recruitment has to be conducted confidentially
- whole workforce start-up and recommissioning projects.

The majority of the comments in the following sections would apply to reactive recruiting in the main.

5.3.5 Attraction

Attraction fundamentally represents the marketing phase of a recruitment program and it is vitally important to have a considered strategy for this process. Consideration must be

given to the message you want to send the candidate market, where you will physically advertise as well as an effective candidate response mechanism. Some common attraction devices include:

- print and electronic media advertisements
- careers sections on company web sites
- social media.

5.3.6 Response management

Effective recruitment campaigns may result in a considerable volume of applicants. How those responses are received, managed and replied to, will have a large bearing on how many of the high quality candidates make it through the process. Response management is also a critical factor in determining how an organisation is perceived in the broader candidate market.

Response management begins when you place a vacancy into the public domain and expose it to potential candidates. You must consider who is likely to see it, how you are instructing those people to communicate with your organisation and then how you will respond to those incoming inquiries. Once these questions are decided and the campaign has gone live, adequate resources must be made available to meet the implied promise you have made to the market.

Response management can include:

- taking the initial call
- replying to messages in a timely fashion
- replying to email or web site registrations
- closing out after phone and in-person interviews
- maintaining contact when delays occur.

For every person who ultimately is offered a job from a public recruitment campaign, there may be several, dozens, or in some cases even hundreds, who do not get the job. How well or not, all of those people are treated will have a significant impact on an employer's market branding.

Handled poorly by using untrained resources to deal with responses, or not doing it at all, can very quickly damage an employer's brand. Done well it can substantially enhance that brand.

5.3.7 Assessment

Once potential candidates have been identified, no matter what attraction devices have been used, consistent assessment processes should be followed. These may include:

- an initial desk-top review of candidate CVs
- a preliminary phone interview
- a face-to-face interview
- other review processes including assessments for
 - various forms of cognitive ability
 - attitudes and behaviours
 - general cultural fit

- reference checking
- qualifications and skills screening
- cultural and team fit.

It is critically important in all cases, that the most appropriately skilled and qualified people conduct each review stage to consistent standards.

Desk-top reviews can be carried out by non-line managers; however, the general approach should be that where there is any doubt about a candidate's potential skills and experience fit, the CV should be referred to a line manager or senior HR/recruitment manager. It is very easy for inexperienced recruiters and other staff to eliminate potentially excellent candidates.

Preliminary phone interviews are important tools for ensuring there is general alignment between a candidate and the organisation's general values, as well as for ensuring terms of employment at a broad level – for example, locations, reporting lines, etc are consistent with a candidate's requirements. Phone interviews are also an important means of assessing a potential candidate's general communication style. With the advent of prevalent email communication, it is easy to overlook that for certain positions, high quality verbal communication skills are essential. A phone conversation will provide insights into a candidate's ability to absorb questions, consider answers and then reply effectively over the phone. A phone interview can save considerable time and expense.

Face-to-face interviews should be carried out by the most experienced line manager or HR manager available.

Note that as well as an assessment process, a face-to-face meeting is also a two-way selling opportunity and should be treated as such. This is the opportunity to present your operation or organisation to the candidate in such a way that it portrays you as an employer of choice, one goal being to ensure that a candidate will accept should an offer be forthcoming.

Other assessments that might be used are wide ranging. The important point is that they should be selected to suit the level of position for which recruitment is being undertaken. Whichever assessment tools are used and whether they are applied by an organisation's internal staff, or whether external consultants are used, they should be applied consistently to all those candidates being considered for similar positions.

Formal reference checking should be a structured process applied consistently to all candidates and based around a standard template of questions. Additionally, the other assessments already carried out from desk-top review, phone interview, face-to-face interview and other assessments, should all reveal some specific areas to be further explored during formal reference checking. These additional questions should be gathered from a formal review of all these previous assessments and should then be asked either throughout the reference check at an appropriate time, or at the end of the reference check.

Qualifications and skills screening is important where a candidate is required to possess certain tertiary or trade qualifications, licences or statutory qualifications. These are sometimes difficult to verify and may require engaging external research sources that are able to approach training and education institutions in other states and countries.

5.3.8 Contract negotiation

An effective recruitment program should have ensured that there is broad alignment between candidate expectations and what an organisation has to offer, well before it comes time to draft a letter of offer. The contract of employment will outline many important conditions of

employment and the process of ensuring there is alignment should start from the very first communication and continue throughout the complete recruitment process.

By the time a letter of offer and contract of employment is presented, it should outline all those elements previously discussed and it should be closely aligned with what is expected. Presenting an offer that is structurally misaligned with a candidate's expectations or one that offers substantially different terms, is a failure not of an organisation's remuneration strategy, but of the recruitment process followed.

Because it is often the case that a number of different people may have had contact with the candidate throughout the review process, it is often an effective strategy to present the broad terms of an offer informally, either verbally or by clearly marking an offer as 'draft for discussion'.

5.3.9 Managing counter offers

Counter offers are becoming a common feature of modern recruitment. A candidate's employer, when presented with the news that an employee is planning on leaving for a different position, will often offer to increase their remuneration, change their responsibility level, offer transfers or change their current position substantially.

If you are the organisation making the offer, none of this is within your control; however, there are things that you can do to reduce the negative consequences of such counter offers.

Start an open dialogue from the very beginning of the assessment process by asking candidate's questions such as:

- Why do you wish to leave your current role?
- Have you discussed these reasons with your employer?
- What did they do about it?
- When you tell your employer that you are leaving what will be their response?
- When they offer to pay you more or change your role to your satisfaction, how will you respond?

This is a very important process that is often underestimated. You need to find out how thorough a candidate has been in terms of their own efforts to make their current role work. The process should also help prepare them for the common counter offer. These things cannot stop the all-too-common counter offer from occurring; however, you will eliminate some candidates much earlier in the recruitment process (and therefore save time and money) if you follow these processes. If you do make an offer and your prize candidate is countered, then following these processes will reduce the impact of that counter offer.

5.3.10 Common recruitment terminology

Active candidate: a candidate proactively looking for a job. They are likely to have registered with recruitment firms and to receive job alerts and regularly scan print media and job boards.

Competency-based interview: typical questions used in such interviews ask candidates to describe real workplace situations they have encountered, how they handled those and what resulted.

Contingent search: where a candidate search is conducted on the basis that a fee is only paid to an agency or recruiter if a placement is made.

Passive candidate: a candidate not actively looking for a new role but one who might be persuaded to apply if they are referred to an opportunity by a third party, often by someone they know or trust.

Proactive search: where a search is conducted with a view to approach a pool, or individual potential candidates, who may not be looking for a new role and who most likely will have no knowledge of the vacancy for which they are being approached.

Psychometric testing: the process of measuring personality, ability and experience via questions and tests. No test is 100 per cent accurate and should be used with professional care and as an adjunct to other assessment tools such as interviews and reference checks.

Retained search: as distinct from contingent search, this is where an agency or recruiter is paid a retainer to commence a search assignment and receives partial payments throughout the assignment. This is more akin to a structured research or consulting assignment.

5.4 REMUNERATION

5.4.1 Purpose of remuneration

The purpose of a remuneration system is to attract, retain and motivate employees in a cost-effective manner. Remuneration is not the primary tool in effective management. Other organisational systems (such as performance management and training and development) have a major impact. Remuneration is a tool that has the capacity to send important signals about what the organisation values and the capacity to reinforce certain behaviours and results.

The foundations of an effective remuneration system are that it:

- promotes internal equity
- is market competitive
- recognises and rewards performance.

Internal equity is concerned with ensuring that the relative value of jobs is recognised. The common formal mechanism used is job evaluation, which is a systematic process of comparing jobs on a range of factors, such as knowledge, problem-solving skills, communication skills and decision making. The selection and weighting of the job evaluation factors can send strong messages about what skills and behaviours the organisation values.

Another common method of determining internal equity is a market-based grading structure that aligns similar jobs (eg technical and engineering staff) in the same grade. This is an easier procedure and can be more transparent to employees.

Market competitiveness is concerned with how well the organisation can compete with others in terms of the salary, perquisites and other benefits it offers employees.

Rewarding performance is another form of equity. It is concerned with the mechanisms used by the organisation to recognise the contribution of groups or individuals and to reinforce that by offering greater financial rewards.

In addition, there is a business need to consider *cost-effectiveness*. It is not effective to offer remuneration levels that are not attractive in the market if they result in high levels of unplanned turnover or in expensive recruitment campaigns that fail to attract suitable candidates. Paying above market rates is not good business unless the additional payroll costs are reflected in better than average organisational performance or some other market advantage.

5.4.2 Structure of remuneration

Remuneration structures in Australian mining usually consist of some or all of the items listed in Table 5.4.1.

TABLE 5.4.1
Examples of remuneration structures in Australian mining.

Component	Example	Purpose	
Base salary		Reflects contribution	Fixed
Other fixed cash	Site/shift allowances	Reflects hardships	
Perquisites	Motor vehicle	Reflects status	
Benefits	Superannuation / health insurance	Reflects needs	
Short-term reward	Bonus/incentive	12 month horizon	Variable
Long-term reward	Equity or other	Growth of organisation	

5.4.3 Remuneration terminology

Several terms are common across the industry:

- base salary
- total fixed remuneration
- total variable remuneration.

Base *salary* is the basic cash component of the remuneration package. Traditionally, it has been the benchmark for remuneration management and has been used for the calculation of other benefits (eg superannuation entitlement or incentive payment).

Total fixed remuneration has emerged in recent years as a popular measure of market competitiveness. It represents the guaranteed total value for the job expressed as a single cash amount. Total fixed remuneration = base salary + company superannuation contribution + motor vehicle + other benefits (eg health insurance) + other perquisites (eg mortgage assistance in a capital city) plus the value of fringe benefits tax where that is payable. It excludes site benefits, such as housing assistance and annual leave airfares for personnel in remote locations.

Total variable remuneration = total fixed remuneration + short-term incentive or bonus.

5.4.4 Incentive terminology

Two common terms are used:

1. short-term incentive
2. bonus.

A *bonus* plan gives a general promise of rewards at the discretion of management at the end of the accounting period. The actual amount paid may be influenced by the budget available to reward performance, the actual level of performance and the extent to which others may participate in the reward.

In an *incentive* plan, a contract is established. If the employee achieves certain pre-arranged targets, that employee will receive pre-arranged rewards. This notion of contract is a substantial shift in managerial philosophy from bonus systems.

The different types of reward plans are illustrated in Figure 5.4.1.

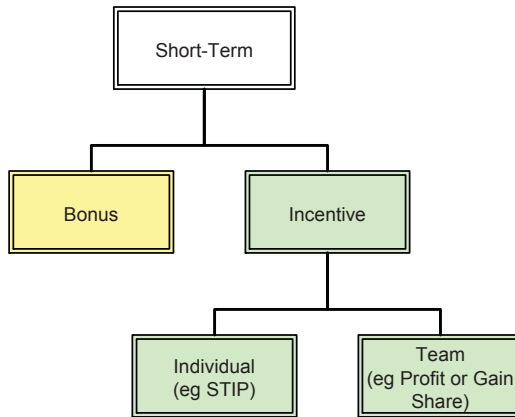


FIG 5.4.1 - Types of reward plans.

Incentive plans can be designed to reward the performance of individual staff (usually senior managers) or reward the performance of groups (eg gain or profit sharing plans).

5.4.5 Market competitiveness

Companies often state where they want to be positioned compared to the labour market in which they compete for personnel. This is termed remuneration policy. The key elements of a remuneration policy are that:

- the labour market is defined, eg the Australian metalliferous mining industry or a subset of that industry such as Western Australian fly-in, fly-out operations
- the key remuneration benchmarking is defined, eg base salary or total fixed remuneration
- the market position is defined, eg base salary at the 75th percentile or total fixed remuneration at the median of the market
- the time of benchmarking is defined, eg at the time of the annual salary review.

An example is: Organisation ABC will set its total fixed remuneration at the median of the Australian metalliferous mining industry effective at the time of the annual salary review on 1 June each year.

5.4.6 Salary reviews

Companies usually review salary levels once each year, although this may happen more often when the market is volatile. Salary reviews aim to integrate several purposes when adjusting individual salaries:

- to reflect changes in the market and ensure competitiveness is maintained
- to recognise individual performance with higher or lower than average increases
- to ensure that remuneration between individuals in similar jobs is fair.

Companies may pay a bonus or short-term incentive to reward performance and/or they may pay an individual higher in a salary grade.

5.4.7 Allowances

Companies may pay an allowance to recognise and compensate for workplace disabilities. Some common allowances are:

- site or location – for isolation, higher costs of living, longer working hours and harsh climatic conditions at a residential mine site
- commute – for the longer hours, separation from family and friends and harsh climatic conditions on a fly-in, fly-out roster
- shift or work pattern – for longer working hours, being rostered at night or rostered over weekends.

A key element in any allowances policy is to distinguish between those elements of a disability that can be compensated with cash (eg longer working hours) and those elements that need to be ameliorated in some way (eg assistance with children's education in remote residential sites).

5.4.8 Design of short-term incentive plans

There is contention about whether cash incentive plans cause or are even associated with improvements in performance. The academic literature is largely of the persuasion that bonus and incentive plans are ineffective. Among mining companies, however, incentive plans appear to be increasing in frequency and impact (ie their contribution to the total remuneration package).

Incentive plans can be effective; however, their design and implementation are critical aspects in respect to their success. The issues that need to be considered include:

- purpose of the incentive plan
- selection of performance targets
- techniques to measure performance
- feedback and control mechanisms
- the proportion of the remuneration package that should be 'at risk'
- basic remuneration (ie base salary or total fixed remuneration) is competitive and reflects internal equity
- design of the plan and ensuring ownership of outcomes
- the regular review of plans.

Organisations have various reasons for introducing bonus and incentive plans. The failure to be specific about the *purpose of the plan* is one of the most common design problems. The range of plan purposes is listed below (it is not exhaustive):

- reward performance
- increase remuneration competitiveness
- improve production or performance
- change workplace behaviour
- increase job security
- change organisation culture
- link rewards to the health of the organisation.

These options are not mutually exclusive and each can be quite valid. The design of the plan will, however, change to accommodate the purpose. The most common problems lie in:

- a failure to specify the purpose
- selecting too many (inconsistent) purposes for the plan to achieve
- selecting a purpose but designing a plan that will not achieve that purpose.

There are two broad options available in framing *performance targets and measures*. These are summarised below:

1. objective 'results' measures (eg performance against budget, return on investment, share price)
2. subjective 'process' measures (eg personal performance in the context of competencies or skills, climate surveys).

The options can be complementary. In practice, objective financial, budgetary or production measures are used with senior operations managers. The measures become progressively more subjective at lower hierarchical levels or when support services are considered.

There is no purpose arriving at the conclusion of the year (or other accounting period) and finding that targets were not achieved and no incentive is payable. Both the organisation and the employee fail to gain any advantage.

The purpose of *feedback mechanisms* is to allow performance to be regularly reviewed and opportunities for improvement identified. Organisations frequently do not budget for the costs and resources involved in providing regular and meaningful feedback. Sometimes synergies are possible with other organisational planning activities, such as the budgeting (review) process. Table 5.4.2 shows how the measures interface and how regular feedback can be provided.

TABLE 5.4.2
Relative impact of corporate/department/individual performance measures.

Position	CEO/MD	Executive manager	General manager	Operations manager	Super-intendent	Shift supervisor
Measure	Corporate 100%	Corporate 30%	Corporate 20%	Corporate 10%	Department 30%	Department 20%
		Department 50%	Department 40%	Department 40%		Individual 70%
			Individual 40%	Individual 50%		
		Individual 20%				
Total	100%	100%	100%	100%	100%	100%

The example provides the employee with feedback on how his or her incentive pay-out is progressing. Performance can be regularly reviewed and updated and this provides live updates on the impact on the pay-out.

Best practice specifies that there should be a direct 'line of sight' between the targets and the employee's ability to influence the result and that risk should be related to the ability to have any impact on organisational results. There is clear evidence in the Australian mining industry between seniority in the organisation and the *amount 'at risk'* as illustrated in Table 5.4.2 (McDonald & Company (Australasia), 2012).

As a general observation, *basic remuneration should be fair*. Employees may react negatively when the amount at risk exceeds their expectations and industry standards. Excessive rewards may lead to unacceptable levels of risk taking.

A key consideration in any short-term incentive plan is that *employees have ownership*. This is achieved when they believe the performance targets are relevant, the performance measures are fair and achievable and the results are valuable (see Figure 5.4.2).

FIG 5.4.2 - Links between various performance measures and cash rewards.

There is debate about whether it is possible that employees can be objective about designing plans for their own reward. There is, however, merit in involving employees in the design of plans in a disciplined and well managed way. Importantly, the limits of input need to be communicated at the outset (eg management retains responsibility for determining the amounts to be paid). Employee input can lead to more realistic plans that enjoy the commitment of participants.

5.5 WORKPLACE TRAINING

5.5.1 Overview of workplace training

It is the duty of a mine manager to ensure that all employees are competent to perform the work assigned to them and that they have been instructed in safe work procedures. Trained and competent employees are key in ensuring a safe and healthy workplace and safe systems of work.

The activities involved in workplace training consist of:

- training needs analysis
- documenting how tasks are to be performed to eliminate or minimise those hazards
- providing training to workers in how the tasks are to be performed
- assessing the performance of the worker after training
- maintaining records of training and proficiency.

Workplace training offers other advantages to the organisation. Competent employees are more likely to be productive and efficient – this provides the opportunity for a competitive edge in mining activities and greater satisfaction to employees as they undertake their duties.

Workplace training can also provide an objective system for promotion and salary increases. Skills-based remuneration is a system where blocks of tasks are grouped together. Demonstrated competence in all of those skills may lead to increased remuneration. These systems also have to be linked to the organisation's need for and ability to effectively deploy workers with those skills, eg there is little point in having an entire underground crew of 20 trained and paid as jumbo operators when there are only two machines to be deployed.

5.5.2 Training needs analysis (TNA)

Training needs analysis requires a systematic approach to examining the organisation, the tasks to be performed and employee capability.

Organisation analysis focuses on the cultural and structural factors that will assist or not assist the training activity. These structural issues may include:

- the availability of organisation training staff or the budget to employ them
- the history of training activity at the operation or in the organisation
- the availability of external resources to assist in design or administration of the training.

The underestimation of the resources and budget required to implement or maintain workplace training is one of the most common problems encountered at an operation.

Task analysis is concerned with the jobs to be performed and the key activities for safe and efficient performance. A critical element of task analysis is *job analysis*, which examines each role and its environment. It is a systematic process that aims to collect data about a range of items such as:

- the purpose of the job in the production process
- the duties to be performed – their sequence, time allocation and the tasks/outcomes critical to success
- job responsibility – how work is allocated, decision-making responsibilities and decisions that are critical for success
- the equipment operated
- the physical demands of the job
- identification of workplace hazards
- planning activities
- the standards for judging the level of performance.

There are many sources of data about jobs and tasks. These can include:

- interviewing (multiple) job holders about their activities – the more interviews, the more likely gaps will not exist
- observing workers perform their jobs
- mining and health and safety standards may define procedures for particular activities (eg work at heights or entry to vessels)
- accident and incident reports may highlight activities that pose a high risk of injury.

The involvement of employees and their supervision in the analysis process is very important. Research suggests that interest in and motivation towards training is enhanced by their early involvement in designing the program.

Employee capability concentrates on the experience and competencies of employees at the mine. It may be necessary to look beyond the current situation. In times of high turnover and challenges in recruiting experienced personnel it will be necessary to consider the changing nature of the workforce and plan for that as well. The introduction of new technology or production methods may mean that a highly experienced and competent workforce today may not be equipped to deal with work requirements in the future. It is the mine manager's responsibility to ensure the workforce is equipped through training to deal effectively and safely with the changes.

5.5.3 Safe work procedures

This activity is closely related to those in undertaking the TNA. It involves:

- the identification and documentation of hazards
- preparation before starting particular tasks (eg personal protective equipment to be used or tools and parts that should be available prior to starting)
- description of a logical, detailed and comprehensive method of performing the work
- determining 'the correct' way to undertake tasks where the risk of injury is high.

Substantial resources were once required to develop safe work procedures; however, intranet systems and other information technology now permit better solutions to be developed. A broad range of operators, technical experts (eg mining engineers and metallurgists) and health and environmental experts can have input into work procedures to ensure they are comprehensive, efficient and safe for workers and the environment.

The challenge is often where to commence this activity. The decision will be influenced by risk management priorities. Tasks that pose threats to personnel, the environment and equipment will usually be addressed with greater urgency. There is a distinct advantage in developing safe work procedures according to a predetermined plan. Demonstrating the effectiveness of the first safe work procedure can make the development of the second, third and fourth much easier.

The development of a template that has wide acceptance by all stakeholders will permit the broader involvement of other workers in documenting a wider range of work activities. It is critical that 'domain experts' be appointed to manage and be responsible for the finished products in each area. Finally, however, the mine manager is accountable for the safe work procedures used at a site.

5.5.4 Delivering training

The delivery of training is a broad and complex area. These comments are consequently superficial at best. For management the issues to be addressed include the following:

- identification and deployment of the resources to deliver training
- clear definition of the expected outcomes of training modules
- instructional materials including the time allocated for training, an explanation of the content and resources needed (eg equipment, hand-outs or access to a location)
- a clear understanding of the tests that will be used to assess competency
- a mechanism whereby the trainees can provide feedback on the training delivered
- processes for recording the training delivered and the results.

Budget, location and the skills profile of the workforce will all have some impact on the choice or choices about the *resources to deliver training*. The options include employing specialist workplace trainers for the site or within departments; including training as a responsibility of some workers or some supervisors; or, using an external service provider.

There should be a clear, documented definition of *the expected outcomes and specific training objectives* for each training activity. They should be brief, detailed and measurable. Examples include:

By the end of this training session you will be able to:

- *list the hazards involved in mixing cyanide*

- carry out the hazard inspection before starting a mine haul truck
- replace the bearings on the hydraulic lifter following the documented procedure.

Tests of competency are critical to ensure that the employee can perform the tasks safely and efficiently. As a mine manager you need some objective; test that the personnel you employ are competent for their own safety and the safety of others.

Tests can take many forms. To test theoretical knowledge, multiple choice tests or a written essay may be suitable, although you need to be sure that a written test doesn't unfairly discriminate against people who are not literate in English.

For many mine operations, practical tests of competency are required. It must be more than a general comment about being competent. In the job analysis, specific clusters of activities will have been described as part of the overall requirements for the job. The test should address these in detail. For example, for a haul truck operator, specific observations could include:

- carries out the hazard inspection and start-up procedure correctly
- starts the vehicle and checks all lamps and gauges before moving
- reverses correctly on spotter's instructions
- correctly positions truck next to the shovel.

The mine manager needs to be assured, through testing, that workers are competent to carry out the tasks that form their jobs.

There needs to be a process that allows *trainee feedback* on the training process and its outcomes. Typically trainee feedback is sought immediately after the training but there is good reason to conduct a second feedback session after the trainee has been working on the job.

The purpose of the feedback is to identify strengths and weaknesses in the training such as whether:

- the goal and objectives are clear
- the instructions are clear; and importantly, when conducted some time after the initial training session whether there were aspects of the task that were not addressed or have changed.

Recording that training has taken place and its results are important for the mine manager to establish that an effective system of training exists and that employees have been trained and assessed to be competent.

5.5.5 A training model

There is great difficulty in prescribing the ideal training model because it will be different for different tasks and in different circumstances. Set out in Figure 5.5.1 is a model that could be used in a variety of (but not all) circumstances.

Before an employee begins work either as a new employee or an existing employee in a new area or on a new task, formal instruction is given in the tasks to be performed, the hazards involved and the correct procedures to complete the job.

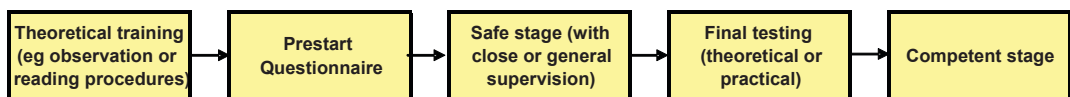


FIG 5.5.1 - A model for on-the-job or workplace training.

Prior to entering the work environment, a test (prestart questionnaire) is conducted to establish that the hazards are recognised and key procedures understood.

The employee may then enter the workplace and be considered as 'safe', subject to close or general supervision depending on the task.

After comprehensive training and supervised experience, the employee may be required to complete further theoretical or practical tests to establish competency to perform the task or the job.

5.6 PERFORMANCE REVIEW SYSTEM

5.6.1 The performance review system

The primary goal of the performance review system (PRS) is to ensure the organisation's objectives are achieved, and the method of achieving them is aligned with the values of the organisation and consistent with legislative requirements. The PRS has a critical human resources dimension as it endeavours to maximise the use of human resources to deliver business outcomes, and to grow and develop human and organisational capability so that outcomes can be achieved more efficiently over time. The key dimensions of this system include processes related to objective setting, expected values and behaviours and individual development and feedback.

The PRS answers the following five questions:

1. *What* do I have to achieve?
2. *When* do I have to achieve it?
3. *What* resources are available to me?
4. *How* am I going to achieve it?
5. *How* am I doing?

The following strategies have been developed to address these questions and enable an organisation to achieve its objectives.

OBJECTIVE SETTING – WHAT DO I HAVE TO ACHIEVE, WHEN DO I HAVE TO ACHIEVE IT AND WHAT RESOURCES ARE AVAILABLE TO ME?

Many organisations conduct a formal planning process to determine objectives to be achieved over one-year, three-year and five-year periods. The sophistication and duration of the objectives developed from business planning will depend on the exigencies of the organisation, its markets, stakeholder expectations and business environment.

The business planning process should feed into the annual budget setting process. The budget process will determine the cost of the resources necessary to achieve the objectives arising from and identified in the business planning process. The budget setting process resolves what the organisation requires and what it can provide to support the achievement of approved objectives.

The key outcomes of the business planning and budget process that feed into the PRS are objectives that are:

- clear
- time bound
- measureable within an overarching business context.

Organisations typically cascade business objectives on a top-down basis, although effective objective setting processes ensure input is received at each organisation level to ensure alignment. *Implementing business objectives effectively by agreeing upon the timing, cost and resource allocation with each employee at each organisation level within a business is the core of an effective PRS. Each participant in the system must be able to answer the five PRS questions in relation to their role.*

The duration and complexity of an individual objective will vary according the size, seniority and complexity of a role. For example, at general management level an objective may cover three or more year's duration, which must be broken down into smaller functional objectives to be achieved during 12 month intervals. The measurement of a general management objective may also be as much qualitative as it is quantitative. At junior levels within an organisation objectives are usually much simpler and of shorter duration. For example, an operator may have a daily production/grade objective with an overarching safe practice requirement.

The outcome of the objective setting process with each employee should arrive at objectives that are specific about what is to be achieved; they are time bound with a date by which they must be achieved, and are measurable. In addition, the objectives must be appropriately resourced and have a reasonable probability of being achieved in the prevailing business environment.

ORGANISATION VALUES AND BEHAVIOURS – HOW AM I GOING TO ACHIEVE MY OBJECTIVES?

The importance of establishing the means by which objectives are achieved in organisations has been evidenced by high profile organisations failings, such as Enron in the USA. The importance of a positive organisation reputation and demonstrated good corporate governance has never been higher in modern corporate history. While governments continue to legislate against unlawful and inappropriate conduct by executives, most organisations proactively establish internal standards via specific governance policies and employee codes of conduct to reduce this risk across their workforce. An effective PRS is an important vehicle to both establish and reinforce what the organisation expects of its employees in how they achieve their objectives.

Organisation values and behaviours focus on common values that apply at the individual level for all employees, and expected behaviours for how employees should interact with each other internally, and with external stakeholders to the organisation. The specific values decided upon will depend on the focus and needs of the organisation but typically relate to values such as individual integrity, honesty, results, cost focus and continuous improvement. Behavioural expectations will also vary significantly but generally focus on relating fairly and equitably with others within the organisation, and professionally, commercially and positively with people and organisations external to the organisation.

For the purposes of the PRS, expectations regarding the values expected of an individual, and the demonstrated behaviours in achieving their objectives must be clearly articulated in documenting objectives for the individual.

PERFORMANCE REVIEW – HOW AM I DOING?

An effective performance review process should be designed to provide participants with the means and opportunity to be successful in the achievement of their objectives, and to develop the capability to achieve increasingly challenging objectives for the organisation in the future. The essential components required for the performance review process include:

- A role description that clearly articulates what is required of an individual in their role, their primary accountabilities, key relationships within the organisation and the knowledge, skills, experience and behaviours necessary to perform effectively in the role.
- A development plan that identifies how the individual will develop their capability and skills within the organisation over time.
- An objectives schedule that outlines the objectives to be achieved during the performance period, specifying what is to be achieved, by when they are to be achieved, with necessary resources identified, and in what manner they are to be achieved. The objectives schedule should also include a timetable of structured meetings for the manager and their colleague to discuss the ongoing achievement of formally stated objectives and day-to-day role requirements, including unexpected events.

The performance review process commences with a well-defined role description. The role description provides the organisation context of the individuals' role and the purpose of the role. The role description provides a platform for the performance review process, describing core tasks, accountabilities, required skills and knowledge and the expected behaviours of the individual. Individuals are provided a clear description of what is expected of them in their role, how they will be assessed with respect to performance, and identification of skill development areas through the provision of this document. The role description is a dynamic document that should be reviewed regularly in the performance review process to identify:

- changes in accountabilities of the role
- areas for individual development relative to the requirements of the role
- performance against the core accountabilities of the role.

An individual development plan identifies and records the outcome of a development discussion. The development discussion is both retrospective and prospective, as it explores skill and capability gaps identified in meeting the requirements of a role, and establishes the development objectives for an individual to meet the ongoing and future role requirements. The development plan also takes into account the career and progression hopes and expectations of an individual in identifying development objectives and opportunities. The development plan should be reviewed regularly, at least annually, or at the time change of role. Development plan discussions should be conducted separately and at a different time of the year from performance review discussion to avoid them being a performance discussion.

The annual performance review should be the result of a series of documented discussions over the course of a performance year. A properly conducted performance review should not result in any surprises for the manager or colleague due to the consistency of dialogue throughout the process. An effective performance review discussion typically embodies the following elements:

- it is a regular two-way dialogue about ideas and issues between manager and colleague over the course of the performance year
- the discussion openly acknowledges good and poor performance, addressing areas for ongoing improvement
- a review of the objectives and target established at the commencement of the performance year to ensure ongoing alignment and, where necessary, reshaping priorities
- a review of ongoing training and developments that need to be included and addressed separately in the individual development plan
- the process culminates in an overall performance assessment.

The performance review process culminates in a performance review assessment that is reviewed with the individual in the first instance. The assessment is then subject to final review and approval by the managers' manager. Assuming the above process has been followed diligently, the performance assessment outcome should be relatively clear to both participants in the review process. An effective performance assessment should take into account the following:

- how well assignments have been completed with respect to quality, timing and behavioural requirements
- behaviour of the individual as a team member
- effectiveness of the individual as a team leader (assuming this is an aspect of their role)
- feedback from colleagues, customers and support providers on the interaction with them in the achievement of individual objectives
- any unplanned events that may have impacted the colleagues' performance either positively or negatively during the performance period.

Completion of the performance assessment phase should result in a document that articulates the results of the review discussion that both parties sign prior to the next review.

5.6.2 Conclusion

This section has endeavoured to describe the elements of an effective performance review system. This system answers the questions of what do I have to achieve, when do I have to achieve it, and what are my available resources, through the objective setting process. The question of how am I going to achieve it, is answered through the establishment of organisation expectations around values and behaviours. The question of how am I doing is answered through the performance review process, which includes a role description, personal development plan and performance assessment dialogue.

5.7 INDUSTRIAL RELATIONS AND EMPLOYMENT

5.7.1 Overview

The *Fair Work Act 2009* (Cth) (FW Act) applies to 'constitutional corporations' (ie 'Pty Ltd' or 'Ltd' companies) and therefore regulates employment and industrial relations for the vast majority of employers and employees in Australia.

The FW Act has established Fair Work Australia (FWA), which is a tribunal that has powers to set a safety net of minimum wages and employment conditions; authorise industrial action; resolve disputes, etc.

The FW Act heralds a return to a highly regulated system of industrial relations that places unions at the centre stage.

5.7.2 Enterprise bargaining

The FW Act provides for good faith bargaining, restrictions on the content of agreements, a single stream of collective enterprise agreements, an enhanced role for union officials as bargaining representatives and participants in dispute resolution and a streamlined process for approval. There is no provision for the making of individual statutory agreements.

ENTERPRISE AGREEMENTS

The FW Act provides for the making of an agreement known as an ‘enterprise agreement’, which is simply a collective agreement that covers one (single-enterprise) or more employers (multi-enterprise) and the employees specified in the agreement (ie the scope of the agreement).

Both single-enterprise agreements and multi-enterprise agreements can be made as a ‘greenfields agreement’ if they relate to a genuine new enterprise and are made prior to the employment of any employees that will be necessary for the normal conduct of the new enterprise. The FW Act does not allow employer-only greenfields agreements. The only greenfields agreements that can be made are those where a union(s) is involved that is entitled to represent the majority of employees to be covered by the enterprise agreement.

HOW DOES BARGAINING BEGIN?

When an employer initiates bargaining under the FW Act it must take all reasonable steps to give notice to employees (who will be covered by the proposed agreement) of their right to be represented by a bargaining representative (*notification time*).

BARGAINING REPRESENTATIVES

Once the obligation to give notice is triggered, employers are obliged to inform the employees to be covered by the proposed agreement of their right to be represented by a bargaining representative within 14 days of any of the above occurring.

Both employers and employees can appoint a bargaining representative for a proposed enterprise agreement.

MAJORITY SUPPORT DETERMINATION

An employee’s bargaining representative (typically a union) may apply to FWA for a majority support determination (MSD). This is likely to arise where an employer refuses to initiate bargaining or agree to it commencing.

This is essentially a poll of employees as to whether they wish to bargain, and if a majority wish to bargain then the employer is required to bargain in good faith. A MSD is a determination by FWA that a majority of the employees who will be covered by the proposed enterprise agreement want to bargain with the employer. These determinations apply *only* in relation to single-enterprise agreements.

The effect of such an order is that it triggers the employer’s obligation to notify employees of their representation rights and commence bargaining in good faith. Once a determination is made it opens the way for bargaining orders to be sought from FWA.

SCOPE ORDERS

A bargaining representative may seek a ‘scope order’ from FWA that resolves concerns about the proposed coverage of a single-enterprise agreement, in terms of the employees it does or does not cover.

A bargaining representative (of an employee or employer) may apply to FWA for a scope order if the representative has concerns that the bargaining for the proposed enterprise agreement is not proceeding efficiently or fairly because the agreement will not cover the appropriate employees.

Enterprise agreements can still be made in relation to geographically, operationally or organisationally distinct groups of employees.

Good faith bargaining

All bargaining representatives for an enterprise agreement must meet the ‘good faith bargaining requirements’ set out in the FW Act. If a party does not meet the requirements, FWA can make a bargaining order to redress the breach.

A bargaining representative must:

- attend, and participate in, meetings at reasonable times
- disclose relevant (but non-confidential) information
- respond to proposals from other representatives in a timely manner
- ‘recognise’ and bargain with other representatives
- give genuine consideration to the proposals of the other bargaining representatives and give reasons for responses to those proposals
- refrain from ‘capricious or unfair conduct that undermines freedom of association or collective bargaining’.

An employer is not compelled to reach an agreement or to make concessions as part of the good faith bargaining requirements.

APPROVAL OF AGREEMENTS

FWA has responsibility for approval of enterprise agreements. Before approving an agreement, FWA must be satisfied that, among other things, the content of the agreement pertains to matters relating to the employment relationship, that all parties genuinely agreed to the enterprise agreement and the agreement does not contain unlawful content.

FWA must also ensure the enterprise agreement passes the better off overall test (BOOT). That is, FWA must be satisfied that the agreement makes each employee better off overall when compared to the terms and conditions of the relevant modern award.

An agreement comes into operation seven days after approval by the FWA.

5.7.3 Industrial action

The FW Act sets out the requirements of lawful industrial action. Industrial action continues to be a significant feature of the industrial landscape.

OVERVIEW

The FW Act contains a central distinction between ‘protected’ industrial action (that is, lawful action) and ‘unprotected’ industrial action (unlawful action). However, a designated ‘bargaining period’ during which industrial action is protected no longer exists, as was the case under the former legislative regime.

Industrial action is permitted for the purpose of supporting or advancing claims in relation to an enterprise agreement that is about, or is reasonably believed to be about, ‘permitted matters’. Permitted matters are essentially matters pertaining to the relationship between an employer and employee, although the definition has expanded to also include matters pertaining to the relationship between the employer and the union.

One significant feature is that employers do not have the ability to pre-emptively lock out employees. A lock out is available only as a response to planned employee industrial action.

The industrial action is termed ‘employee claim action’, ‘employer response action’ (in response to the initial industrial action) and ‘employee response action’ (in response to the employer’s industrial action). Note that an employer cannot pre-emptively lock-out employees – the action can only be taken in response to protected industrial action taken by the employees.

WHAT IS ‘INDUSTRIAL ACTION’?

Industrial action means:

- the performance of work by an employee in a manner different from that in which it is customarily performed, or the adoption of a practice in relation to work by an employee, the result of which is a restriction or limitation on, or a delay in, the performance of the work
- a ban, limitation or restriction on the performance of work by an employee or on the acceptance of, or offering for, work by an employee
- a failure or refusal by employees to attend for work or a failure or refusal to perform any work at all by employees who attend for work.

Picketing generally does not constitute industrial action, although it will often constitute a legally actionable tort.

CAN AN EMPLOYER SEEK TO SUSPEND OR TERMINATE INDUSTRIAL ACTION?

The FW Act allows for suspension or termination of industrial action.

Section 418 of the FW Act provides that FWA *must* order that industrial action by employees (or employers) be suspended or terminated if it appears to FWA that industrial action that is not ‘protected industrial action’ is happening, is threatening, impending or probable, or is being organised. FWA may make an order on its own initiative or on application by a person affected by the industrial action, or by an organisation of which a person affected by the action is a member.

An injunction may also be sought in the Federal Court under section 417 if industrial action is engaged in during the operation of an enterprise agreement by persons or organisations covered by the agreement.

Protected industrial action may also be suspended or terminated if the action causes, or is likely to cause, ‘significant economic harm’ to the employer or to any of the employees who will be covered by the agreement. The economic harm at issue must be ‘imminent’. Third parties affected by the industrial action suffering ‘significant economic harm’ may also bring an application to suspend or terminate the protected industrial action.

The other grounds for suspending or terminating protected industrial action continue where life or personal health or safety is or will be endangered; or there is or will be significant damage to the Australian economy (2011 QANTAS dispute). The Workplace Relations Minister may make a declaration stopping industrial action, with the exception that the Minister cannot make a declaration on the grounds of the adverse effect of the industrial action on the employer.

NO PAYMENT FOR INDUSTRIAL ACTION?

Under the FW Act, an employer cannot pay the employee(s) who take *unprotected industrial action* for the total period of time during a day in which unprotected action is taken (with a minimum deduction of four hours).

In general, payment for any period where an employee has failed or refused to attend work, or attended but failed or refused to perform any work at all (ie strike) is prohibited only for the total duration of the *protected industrial* action taken by an employee on a day. Special rules apply for partial work bans and overtime bans.

5.7.4 Union rights of entry

The FW Act provides significant rights of entry (ROE) for unions and potentially provides unions with a powerful recruiting weapon.

There are three types of ROE for union officials seeking to enter ‘workplaces’ under the FW Act:

1. to hold discussions with employees whose interests the union is entitled to represent
2. to investigate suspected contraventions of the FW Act, industrial instruments and like instruments
3. to investigate state occupational health and safety (OH&S) matters.

FWA may issue a federal ROE permit to a union official if it is satisfied that the official is a fit and proper person to hold the permit.

UNION RIGHTS OF ENTRY TO HOLD DISCUSSIONS

Under the FW Act, a union official has the right to enter a workplace to hold discussions with employees during meal or other breaks as long as the union is entitled to represent those employees. The union does not need to be bound by an award or collective agreement that applies in the workplace. There is also no need for the union to have any members in the workplace. This new provision clearly allows unions that have had no presence in a workplace to enter, hold discussions and, in practice, to recruit new members.

The union must give written notice (eg by mail, by facsimile, hand delivered) during working hours of at least 24 hours before the proposed entry but no more than 14 days before the proposed entry specifying which provision of the union rules entitles the union to represent the employee(s).

The proviso that employees must wish to participate in discussions operates only after entry. The union official does not need to demonstrate before entry that there is a particular employee(s) on the premises who wishes to talk to the union official.

RIGHTS OF ENTRY FOR OCCUPATIONAL HEALTH AND SAFETY PURPOSES

A duly accredited union official can seek a ROE for the purpose of investigating a suspected breach of state OH&S laws. To exercise ROE, the union official must be able to:

- show that they hold the relevant federal ROE permit and an authority issued by the relevant state industrial tribunal to exercise a ROE for a State OH&S right (double permit requirement)
- show that there are employees on the site who are eligible to join the official’s union
- describe in general terms the nature of the alleged suspected OH&S breach that it is investigating
- as well as the ROE permit, it must also show that it has authority under the relevant state laws and from the relevant state OH&S body to investigate the breach.

If the above conditions are met, the union official can enter the premises without prior notice to the employer. However, written notice must be provided to the employer if the union official also intends to inspect documents.

If the union official intends to access, inspect or make copies of ‘employee records’ (or other documents) relevant to the suspected breach that are kept on the premises, the union official has to give the occupier and any affected employer written notice of no less than 24 hours of its intention to do so.

RIGHTS OF ENTRY TO INVESTIGATE CONTRAVENTIONS

A duly accredited union official can seek a ROE for the purpose of investigating a suspected contravention of the FW Act, the former *Workplace Relations Act 1996* (Cth) or ‘industrial instruments’.

The union official can enter only during working hours and must first:

- show a current federal ROE permit
- have given written notice in the approved form to the occupier and any affected employer at least 24 hours before the attempted entry
- declare on the ROE notice that the union is entitled to represent the industrial interests of at least one member who works on the premises
- specify the particulars of the suspected contravention(s).

There is no right for the union official to wander the premises at large. The union official can only inspect the areas of the premises that are relevant to the investigation of work, processes or objects relevant to the suspected contravention.

The union official must agree to:

- hold interviews in the room or area (suitable for the purpose) that they are directed to use by the employer
- take a particular route to that room or area and not to deviate from that route
- comply with all the OH&S requirements at the site.

5.7.5 The safety net

The safety net consists of the ten National Employment Standards (NES) and modern awards, and sets the minimum terms and conditions of employment for all employees in the federal system. Set out below is a snapshot of particular elements of each NES entitlement. An employer must comply with the NES in relation to each of its employees.

A SNAPSHOT OF THE NATIONAL EMPLOYMENT STANDARDS

- Maximum weekly hours of work (38 hours plus reasonable additional hours)
- requests for flexible working arrangements (employer may refuse request on reasonable business grounds)
- parental leave
- annual leave (20 working days paid annual leave per year)
- personal/carer’s leave and compassionate leave
- community service leave
- long service leave
- public holidays
- notice of termination and redundancy pay
- provision of the Fair Work Information Statement.

MODERN AWARDS

Modern awards form the second element of the safety net.

The majority of Australian employees are likely to be covered by a modern award. The modern awards apply to employees and employers on an industry-wide or occupational basis. However, modern awards will not generally cover those employees who, because of the seniority of their role, have not traditionally been covered by awards. Modern awards will also not apply to high income employees who have 'guaranteed annual earnings' in excess of a threshold amount (\$118 100 for the 2011/12 year and adjusted each year on 1 July). This exemption will only apply if the employer provides a written guarantee to pay the employee annual earnings at or in excess of the threshold.

Although modern awards have been in operation since 1 January 2010, the phase-in/phase-out period commenced on 1 July 2010. The challenge for employees is to correctly apply the transitional provisions as they are phased in over the next five years.

It is important that employers take steps to ensure compliance with the safety net (NES and modern awards). The Fair Work Ombudsman has a clear charter to enforce compliance and the FW Act imposes penalties (up to \$6600 for an individual and \$33 000 for a corporation) for breaches of terms of the NES or a modern award.

The main modern award relevant to the mining industry is the *Mining Industry Award 2010*. There is also a *Professional Employees Award 2010* that covers engineers and scientists, which may also be relevant. If an enterprise agreement does not apply to an employee, an award will apply *unless* the employer provides the employee with a guarantee of annual earnings that exceeds the high income threshold (currently \$118 100). If this is the case, the modern award will not apply to them and the employer will be free to enter into contractual terms with the employee that might be inconsistent with the terms of the award (for example, flexibility of working hours, etc).

5.7.6 Termination matters

The decision to dismiss an employee is an area of the employment relationship that requires an understanding of a wide range of legislative and other obligations of an employer. The decision is also a significant one in terms of the effect on the employee and the organisation. Not surprisingly, a significant amount of resources, time and effort needs to be devoted to the associated decisions and processes. Knowing the legal risks and obligations involved is essential.

WHO IS COVERED BY UNFAIR DISMISSAL LAWS?

Employees who are earning under the high income threshold (currently \$118 100) excluding superannuation and incentive bonuses or payments (indexed for consumer price index each year) are covered by unfair dismissal laws. In addition, employees who are covered by awards or enterprise agreements made under the FW Act or its predecessor, irrespective of their earnings, will be covered by the unfair dismissal laws.

This is the case except for:

- certain casual employees
- employees who were dismissed during their first six months of employment (or 12 months in the case of stipulated small employers)
- employees engaged on a specified term contract if the ending of the employment is due to the contract not being renewed at its expiry
- certain employees engaged under traineeships.

WHAT DO UNFAIR DISMISSAL LAWS REQUIRE?

Under unfair dismissal laws, an employer cannot dismiss an employee unless they have a valid reason connected with the employee's conduct, capacity or because of a genuine redundancy. In addition, if the dismissal is related to conduct or capacity, it may still be unfair if the employee is not notified of the reason for their dismissal, not given an adequate opportunity to respond to those reasons, not provided with a warning in certain circumstances, not allowed a support person to assist them in discussions about the hearing or if the dismissal was otherwise procedurally unfair.

A valid reason is one that is sound and defensible and related to the employment. Except for serious misconduct (eg theft), if dismissing an employee because of inadequate performance or misconduct, an employer may need to establish more than one incident of misconduct or poor performance to justify the dismissal. In addition, the existence of prior warnings about the employee's misconduct or poor performance will normally be necessary in the sense that the employee has been made aware that failure to improve their performance or conduct may jeopardise their ongoing employment.

In the case of the valid reason, employers need to establish the misconduct on the 'balance of probabilities'. A rigorous investigation of the circumstances is often a key element of satisfying that burden of proof. Employers need to ensure that they have sought and taken into account all relevant evidence and properly tested it and that, prior to any dismissal decision, they have given the employee an opportunity to respond to any allegations against them, including having given them sufficient detail of the matters that may form the basis for dismissal.

An employer should also take into account the employee's length of service, employment record and relevant personal circumstances before making the decision to dismiss.

REMEDIES UNDER UNFAIR DISMISSAL LAWS

A dismissal that is found to be unfair may lead to the employee being reinstated to the position that they were employed in prior to the dismissal or to another position on terms and conditions no less favourable than that position.

This may include an order that the employee be appointed to an associated entity of the employer that dismissed the employee.

If FWA considers that reinstatement is inappropriate, it may instead order payment of compensation to the employee up to a maximum of six months' pay.

DISCRIMINATION AND GENERAL PROTECTIONS

When dismissing an employee, employers also need to ensure that a reason for the dismissal (even if not the only reason) did not include certain protected attributes of that employee, set out under state and federal discrimination laws or under the general protections available under the FW Act, including:

- race, ethnicity, colour, natural extraction or social origin or religion
- age
- disability or impairment
- temporary absence due to illness or injury
- sex or sexual preference
- pregnancy, carer or family responsibilities, or parental or carer status
- having a role as a union delegate or OH&S representative

- union membership or being involved in industrial activities
- making a complaint about occupational health and safety matters or conditions of employment.

It is also unlawful to terminate an employee's employment because they have exercised, or wish to exercise, what is known as a workplace right. An employer is prevented from dismissing employees because the employee:

- is able to or has participated in workplace processes or proceedings
- has the benefit of, or a responsibility under a workplace instrument or law
- is able to make, or has made, a complaint or inquiry to a body or person seeking compliance with a workplace law or instrument.

The general protections protect 'workplace rights' as defined broadly in the FW Act. The general protections prohibit 'adverse action' being taken against a person when that person decides to, or not to, exercise a 'workplace right' or engage, or not engage, in 'industrial activities'. An employee is also protected from adverse action because of their race, colour, sex, age and other grounds.

In essence, the provisions protect employees, employers and independent contractors against unfair, unlawful and discriminatory treatment in the workplace. The FW Act also contains very broad options to remedy conduct that breaches the general protections that provide immediate access to the court system, particularly for some discrimination claims.

An employer may face reinstating the employee or compensating them where they have been found to have unlawfully terminated employment (including acting adversely). Employers may also face significant fines (penalties) for breaching these provisions of the FW Act.

NOTICE

The employee will be entitled to at least the minimum period of notice or payment in lieu of notice stipulated in the FW Act. The notice period depends upon the employee's length of service. Employers should also check any applicable workplace instrument in the event that the notice period is higher than the minimum in the FW Act, in which case the notice provisions in that workplace agreement should be complied with.

Employers also need to check whether an employee may be entitled to a higher period of notice in accordance with their contract of employment. Where the employee has a written employment contract that expressly stipulates the period of notice to apply on termination, and it is higher than any legislative or workplace agreement minimums, then that express notice provision in the contract must be provided.

REDUNDANCY

Where an employee's employment comes to an end because their position is redundant, the employee may be entitled to redundancy or severance pay in addition to any notice of termination or payment in lieu of notice. This entitlement may arise under the NES in the FW Act, under an applicable award (including a modern award), workplace agreement, workplace policy or from the employee's contract. In the case of the employment contract, there may be an express provision entitling the employee to severance or redundancy pay or such a benefit may be implied or otherwise incorporated into the contract – for example, due to the existence of an applicable redundancy policy applying at the workplace.

Employers should also keep in mind that in some cases, an employee is not entitled to redundancy or severance pay in the event that their position is made redundant – for example, if the employer has offered them or arranged suitable alternative employment. Employers need to carefully review the document that provides the redundancy pay entitlement to assess that issue.

The entitlement to redundancy pay is in addition to notice of termination. In the event of a redundancy, an employee will therefore be entitled to receive both redundancy pay and notice of termination.

LEAVE ENTITLEMENTS ON TERMINATION

An employee is also entitled to be paid accrued statutory entitlements such as annual leave and long service leave (if the employee reaches the relevant length of service threshold) upon termination.

Note that the FW Act provides for very limited circumstances for employers to deduct monies from employees outstanding entitlements (including leave and wages) owing. For example an employer cannot deduct monies from an employee for failing to provide the required notice or serve out the required notice period upon termination.

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CHAPTER 6

CAPITAL INVESTMENT AND PROJECT DEVELOPMENT

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6.1 MINERAL RESOURCES AND ORE RESERVES

6.1.1 JORC, VALMIN and other codes

THE JORC CODE

The estimation of the size and grade of, and the consequential value contained within a Mineral Resource and/or an Ore Reserve has been an issue bedevilling the mining industry for the last 455 years. In 1556 Georgius Agricola wrote the following in his seminal book *De Re Metallica*:

A careful owner, before buying shares, should visit the mine and carefully examine the nature of the vein, as it is very important that he be on his guard, to avoid being the victim of dishonest sellers of shares seeking to defraud him (Agricola, 1556).

In more recent times there have been a number of classification systems that have sought to provide a framework for the classification of a Mineral Resource or Ore Reserve prior to the estimation of its value. Following the 'Poseidon Boom and Bust' in the late 1960s, the Melbourne Stock Exchange and Federal Government (Rae Commission) requested the Australian Mining Industry Council (AMIC) to develop a mechanism to resolve the reporting issues.

AMIC responded and joined with AusIMM in 1971 to form the Joint Ore Reserves Committee (JORC), which developed 'The JORC Code' (JORC Code 2004 edition).

JORC set out a series of guidelines on classification and reporting that remained in industry use until 1989 when the first edition of the JORC Code was published. This was immediately incorporated as an appendix to the Australian Stock Exchange (ASX) Listing Rules and remains today the only externally sourced document included in these rules.

ASX resolved to include the JORC Code in its entirety into its Listing Rules for two reasons:

1. Summarising the Code for inclusion in the Listing Rules could have altered the intent and meaning.
2. ASX could rely on the professional bodies to ensure that their members abided by the JORC Code. This is as a result of the professional bodies' membership being required to comply with the JORC Code as part of their Codes of Ethics. Both AusIMM and the Australian Institute of Geoscientists (AIG) have these requirements.

The added benefit of this approach is that, through a sense of continued ownership, the professional bodies have both been prepared to continue education activities related to the use of the JORC Code and to progressively update the Code as usage issues have been identified and resolved. The resolution of these issues has been promulgated through revisions of the Code in 1992, 1996, 1999 and 2004 and the use of ASX Companies Updates, which are available via a linkage from the JORC web site to the ASX web site.

In 1992 the AIG joined the JORC Committee and a second edition of the JORC Code was published. The JORC Committee now has three parent bodies; AusIMM, AIG and the Minerals Council of Australia (MCA), with invited members from the ASX and Financial Services Institute of Australia. In recent years the JORC Committee has developed a sound and professional working relationship with the Australian Securities and Investments Commission (ASIC), the Australian securities market regulator.

The JORC Code provides the standards and guidelines for the Public Reporting of Exploration Results, Mineral Resources and Ore Reserves to the ASX and New Zealand Exchange (NZX) in the NZSX Listing Rules.

The JORC Code is based on the three principles of:

1. *transparency* – the reader of a Public Report is provided with sufficient clear and unambiguous information, so that a reader is able to understand the report and is not misled, ie clear and unambiguous
2. *materiality* – a Public Report contains all the relevant information that investors and their professional advisers would reasonably be expected to need in order to make a reasoned and balanced judgement about the matters being reported, ie all the information reasonably required and expected
3. *competence* – the Public Report is based on work that is the responsibility of a suitably qualified and experienced person who is subject to an enforceable professional code of ethics – a Competent Person, ie public reports are based on work undertaken by Competent Persons.

A Competent Person's competence is gained from a minimum of five years' experience in the estimation of Mineral Resources or Ore Reserves in a particular commodity specific to the Public Report. Overseas competence is recognised through a recognised overseas professional organisation (ROPO) where the organisation can demonstrate a similar enforceable professional code of ethics to that of the JORC parent bodies.

Mine manager's focus

For a practising mine manager, it is important to realise what the JORC Code does and does not do.

It does:

- set *minimum standards for the public reporting (in Australia and New Zealand)* of Exploration Results, Mineral Resources and Ore Reserves
- provide a mandatory system for *classification* of tonnage/grade estimates according to geological confidence and technical/economic considerations (JORC Code Figure 1)
- require Public Reports to be based on work undertaken by a *Competent Person*; describes the qualifications and type of experience required to be a Competent Person
- provide *extensive guidelines* on the criteria to be considered when preparing Public Reports on Exploration Results, Mineral Resources and Ore Reserves (JORC Code Table 1).

It does not:

- regulate the *procedures* used by Competent Persons to estimate and classify Mineral Resources and Ore Reserves
- regulate companies' *internal* classification or reporting systems
- *deal with breaches* of the Code by
 - companies; these are dealt with by the ASX or relevant exchange
 - individuals; these are dealt with under Codes of Ethics of AIG, AusIMM or the relevant ROPO.

VALMIN CODE

The first edition of the VALMIN Code (2005) was published in 1995 by The VALMIN committee, a joint committee of The AusIMM, AIG and the Mineral Industry Consultants Association (MICA).

It has not attained the status of the JORC Code primarily because it is not mandated by the ASX when a public Independent Expert Report is made.

The VALMIN Code provides the standards and guidelines for Public Reporting of Assessment and Valuation of Mineral and Petroleum Assets and Securities to the ASX and NZX.

The VALMIN Code is again a 'principles' based code relying on the same three principles as the JORC Code with the addition of independence of the 'Expert' or 'Specialist' who prepares the Independent Expert Reports. The Code has a broader coverage than the JORC Code by covering valuations of exploration properties to corporate entities.

Mine manager's focus

Once again for a mine manager, it is important to realise what the VALMIN Code does and does not do:

It does the following:

- sets *fundamental principles and supporting recommendations regarding good professional practices to those involved in the preparation of public Independent Expert Reports*
- requires reports to be commissioned by a *Commissioning Entity*
- requires public Independent Expert Reports to be prepared by an *Expert*; describes the qualifications and type of experience required to be an Expert
- describes the qualifications and type of experience required to be a *Specialist* (similar in concept to the JORC Code's Competent Person); who may assist the Expert in the preparation of the Report
- provides extensive mandatory requirements and guidelines on the criteria to be considered when preparing valuation reports.

It does not:

- regulate the procedures used by an Expert or the Specialist to prepare the Report
- regulate companies' *internal* valuation systems
- deal with breaches of the Code by
 - companies; these are dealt with by ASX and increasingly by ASIC, in particular where statements made that are required to comply with the Code are related to raising finance or to major transactions, such as mergers and acquisitions
 - individuals; these are dealt with under the Code of Ethics of AIG, MICA and AusIMM.

RELATIONSHIP BETWEEN JORC AND VALMIN CODES

The JORC and VALMIN Codes are very clearly related through the VALMIN Code's Clause 74:

The Expert or Specialist must comment on the quality and reasonableness of the resource and/or reserve estimate that may be provided, either by the Commissioning Entity or by any other entity that may have an interest in the valuation and the extent to which they have been reported in accordance with the current version of the JORC Code.

Where resource or reserve estimates are not considered to conform with the JORC Code, for example if they were prepared before the JORC Code became applicable or for resources/ reserves located in countries where other or no resource or reserve codes may apply to the extent that it is impractical to report in accordance with the JORC Code, the reasons for

having to base a Technical Assessment and/or Valuation on non-conforming resource or reserve estimates must be indicated in the Report.

An assessment of the quality of such estimates with respect to the JORC Code must also be provided.

OTHER INTERNATIONAL MINERAL REPORTING CODES

The JORC Code has given rise to a number of international reporting codes (Figure 6.1.1).

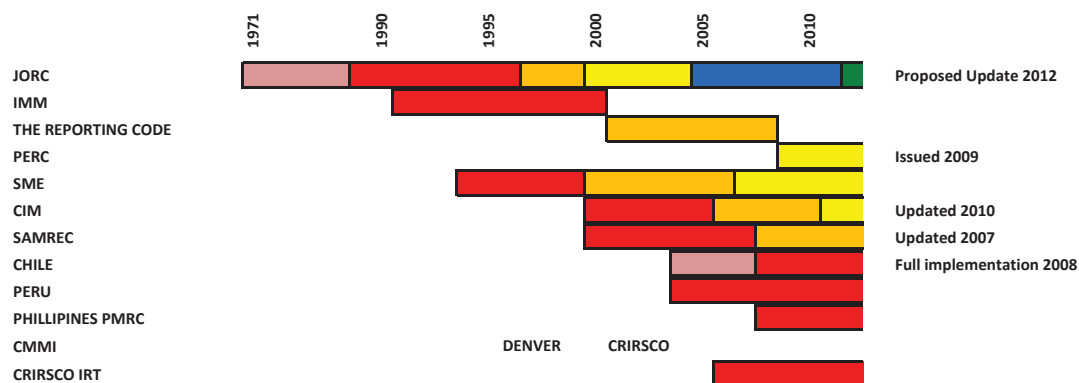


FIG 6.1.1 - Timeline of JORC family of reporting codes for Mineral Resources and Ore Reserves.

The JORC Code has been translated into South American Spanish, Portuguese, Mandarin and Japanese.

In cooperation with the Committee for Mineral Reserves International Reporting Standards (CRIRSCO), the Russian professional body, The National Association for Subsoil Use Auditing (NAEN) together with the government department (GKZ) has developed a new CRIRSCO compatible Russian reporting code for market reporting. Russia was admitted to CRIRSCO in November 2011, following the adoption of the NAEN Code for the international reporting of Russian Mineral Resources and Reserves.

The Russian Government Code and Chinese Codes have been mapped against the CRIRSCO template framework with the aim of bringing these codes closer to the CRIRSCO template.

The American SEC Industry Guide 7 remains outside the CRIRSCO template framework despite a number of attempts by the SME Reserves Working Group to reach a mutually agreeable position with the SEC.

The Canadian National Instrument NI 43-101, which references the CIM Definitions Standards, is more prescriptive than the JORC and SAMREC Codes and is considered in some regulatory quarters to be an easier code to administer as it requires a less intimate knowledge of the nuances and intricacies of Mineral Resource and Ore Reserve estimation.

CRIRSCO at its 2011 meeting finalised a set of standard CRIRSCO Definitions for inclusion in reporting standards of all CRIRSCO members subject to the agreement of the respective National Reporting Organisations (NROs). These definitions aim to produce uniformity between the important definitions in each of the NROs codes and standards and the CRIRSCO International Reporting Template. The aim of this initiative is to allow bodies such as the International Accounting Standards Board to refer to the CRIRSCO Template and be confident this exactly reflects all the national reporting codes and standards. This

could be important if and when mining company's Mineral Resources and Mineral (Ore) Reserves are required to be included in the annual accounts.

OTHER INTERNATIONAL VALUATION CODES

In a similar fashion, a small family of valuation codes has been developed following the introduction of the VALMIN Code (Figure 6.1.2). The Canadian CIMVAL Code and the South African SAMVAL Code are effectively equivalent to the VALMIN Code.

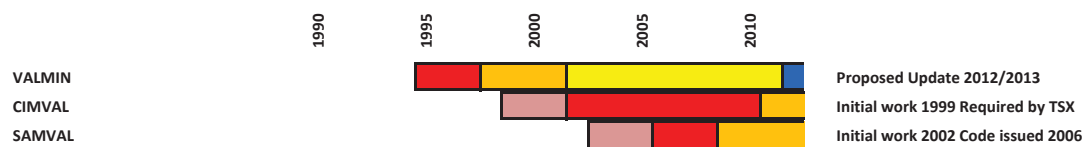


FIG 6.1.2 - Timeline of VALMIN family of valuation codes for mineral and petroleum assets and securities.

CONCLUDING COMMENTS

It is important that a mine manager understands that:

- Mineral Resource and Ore Reserve estimates are *ESTIMATES* only; being based on a competent interpretation of the geology of the orebody and samples, which possibly represent only 0.001 per cent to 0.0001 per cent of the orebody.
- There is no single correct Resource or Reserve estimate for a given deposit.
- The various reporting standards ensure a minimum level of *reporting*, but do not imply that the Resource or Reserve estimate is a good estimate. Only an independent technical audit/review can give this assurance.
- The Mineral Resource estimate represents a realistic inventory that, *under assumed and justifiable technical and economic conditions*, might, in whole or in part, become economically extractable.
- Portions of a deposit that do not have reasonable prospects for eventual economic extraction must not be included in a Mineral Resource.
- It is therefore critical that
 - the data from which the Mineral Resource is estimated is of high quality, reliable, representative and reproducible
 - the geological interpretation and the estimate are carried out by qualified, experienced professionals with at least five years of experience in the mineralisation style being estimated.
- An Ore Reserve is an estimate of tonnage and grade for the economically mineable part of a Measured or Indicated Mineral Resource and its simplest definition is the tonnes and grade that could be expected to be delivered to the mill or treatment plant.
- Realistically assumed modifying factors (mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors) must be taken into consideration when estimating an Ore Reserve.
- The inherent uncertainty in Resource/Reserve estimates is conveyed through the JORC Code's Figure 1 classification, and is not necessarily communicated through quantified confidence limits. All users, including accountants, should take time to understand the underlying uncertainty.

- When in doubt, ‘read the codes’, but note that as the codes are principles-based it is important to read the full Code in order to understand the spirit of the Code rather than ‘cherry pick’ clauses thought to be relevant.

6.1.2 Converting Mineral Resources to Ore Reserves

THE DIFFERENCE BETWEEN MINERAL RESOURCES AND ORE RESERVES

It is not unusual for investors to misunderstand, or be confused by the terms Mineral Resource and Ore Reserves. The belief that the ounces or tonnes of metal contained in Mineral Resources represent what will eventually be produced and sold is not uncommon. The differences may be obvious to those involved in preparation of Mineral Resource and Ore Reserve estimates and the resulting public statements, but a clear understanding of the differences is important to those who approve and prepare the statements for publication. The following definitions of a Mineral Resource and Ore Reserve have been reproduced from the JORC Code:

A ‘Mineral Resource’ is a concentration or occurrence of material of intrinsic economic interest in or on the Earth’s crust in such form, quality and quantity that there are reasonable prospects for eventual economic extraction. The location, quantity, grade, geological characteristics and continuity of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge. Mineral Resources are sub-divided, in order of increasing geological confidence, into Inferred, Indicated and Measured categories.

A Mineral Resource statement provides an estimate of the quantity and quality (grade) of mineralised material in its unmined, *in situ* state:

An ‘Ore Reserve’ is the economically mineable part of a Measured and/or Indicated Mineral Resource. It includes diluting materials and allowances for losses, which may occur when the material is mined. Appropriate assessments and studies have been carried out, and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified. Ore Reserves are sub-divided in order of increasing confidence into Probable Ore Reserves and Proved Ore Reserves.

An Ore Reserve statement provides an estimate of the quantity and quality of material that may actually be mined from the Mineral Resource. It provides the most informed estimate of likely future production from an *in situ* Mineral Resource.

THE RELATIONSHIP BETWEEN MINERAL RESOURCES AND ORE RESERVES

Ore Reserves inherit the geological uncertainty associated with the Mineral Resource from which they are derived. They also adopt the uncertainties associated with the potential mining activities. Ore Reserves can only be derived from Measured or Indicated Mineral Resources. Ore Reserves cannot be derived from Inferred Mineral Resources. The relationship between Mineral Resources and Ore Reserves is shown in Figure 6.1.3.

Indicated Mineral Resources cannot be converted to Proved Ore Reserves. Measured Mineral Resources can be converted to Proved Ore Reserves or Probable Ore Reserves as a result of uncertainties associated with the modifying factors.

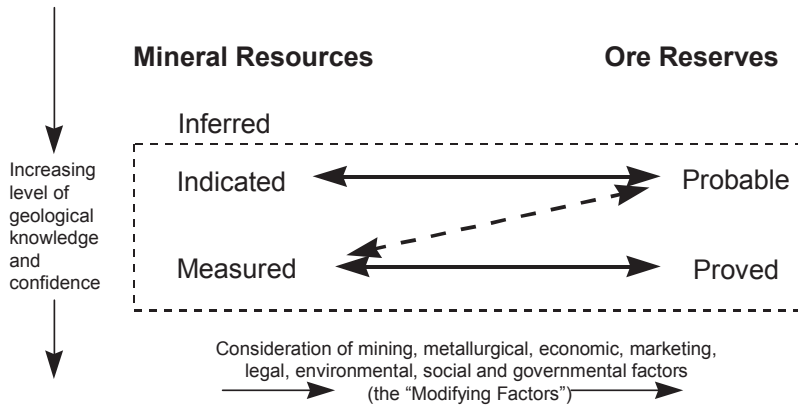


FIG 6.1.3 - The relationship between Mineral Resources and Ore Reserves (source: JORC Code, 2004).

LEVEL OF STUDY FOR CONVERSION OF MINERAL RESOURCES TO ORE RESERVES

Many companies develop a system where the level of study required by the company to satisfy conversion of a Mineral Resource to an Ore Reserve is specified – it is not specified in The JORC Code, but is in some overseas CRIRSCO family codes. The JORC Code provides the following guideline:

In order to achieve the required level of confidence in the Modifying Factors, appropriate studies will have been carried out prior to determination of the Ore Reserves. The studies will have determined a mine plan that is technically achievable and economically viable and from which the Ore Reserves can be derived. It may not be necessary for these studies to be at the level of a final feasibility study.

The Canadian Institute of Mining, Metallurgy and Petroleum in the CIM Definition Standards on Mineral Resources and Mineral Reserves requires that the economically mineable part of an Indicated and, in some circumstances, a Measured Mineral Resource be demonstrated by at least a preliminary feasibility study. The Standards define a preliminary feasibility study as follows:

A preliminary feasibility study is a comprehensive study of a range of options for the technical and economic viability of a mineral project that has advanced to a stage where a preferred mining method, in the case of underground mining, or the pit configuration, in the case of an open pit, is established and an effective method of mineral processing is determined. It includes a financial analysis based on reasonable assumptions on mining, processing, metallurgical, economic, marketing, legal, environmental, social and governmental considerations and the evaluation of any other relevant factors which are sufficient for a Qualified Person, acting reasonably, to determine if all or part of the Mineral Resource may be classified as a Mineral Reserve.

ESTIMATION OF ORE RESERVES

It is important to remember that in most cases the purpose of preparing Ore Reserve estimates is to enable the Reserves to be publically reported. Estimates of tonnage and grade (mining inventory estimates) not for public reporting that are outside of the categories covered by the JORC Code may be useful for a company in its internal planning and evaluation processes. To avoid confusion it is best that these mining inventory estimates are not referred to at any stage as Ore Reserves.

There is no prescribed process for estimating Ore Reserves or for determining the modifying factors. The JORC Code requires that documentation detailing Ore Reserve estimates from which a public report on Ore Reserves is prepared, must be prepared by or under the direction of, and signed by, a competent person or persons. The Code describes a competent person as follows:

A 'Competent Person' is a person who is a Member or Fellow of The Australasian Institute of Mining and Metallurgy and/or the Australian Institute of Geoscientists with a minimum of five years' experience which is relevant to the style of mineralisation and type of deposit under consideration and to the activity which that person is undertaking. If the Competent Person is estimating, or supervising the estimation of Mineral Resources, the relevant experience must be in the estimation, assessment and evaluation of Mineral Resources. If the Competent Person is estimating, or supervising the estimation of Ore Reserves, the relevant experience must be in the estimation, assessment, evaluation and economic extraction of Ore Reserves.

The process and the inputs for estimating Ore Reserves are left to the Competent Person or Persons to determine. However, the following are generally applied as good practice:

- The Mineral Resource model used for Ore Reserves estimation should be prepared such that it is compatible with the style of mineralisation and the mining method to be used for estimating Ore Reserves. Typically, a model developed on the assumption that the Resource would be mined using open pit methods at a low cut-off grade is likely to be unsuitable as a basis for estimating Ore Reserves in the deeper parts of the deposit using underground methods.
- Mining outlines must be practical. This applies to both open pit and underground mining. In the case of open pit, this is generally considered to involve preparation of a pit design, including haul roads and pit wall designs that take into account geotechnical and practical operating considerations. A simple pit shell produced using typical pit optimisation software is unlikely to be a suitable basis for Ore Reserve estimation. In the case of underground mining, the planned excavations, access development, ventilation arrangements and other underground mining considerations must be designed to the point that they demonstrate practicality.
- The Reserve may include dilution that is not part of the underlying Mineral Resource. It may also include uneconomic blocks where it is impractical to exclude them from the Ore Reserve. Various cut-off grades may be used to estimate the Ore Reserve providing processing the material is economically justified. The inclusion of diluting material in Ore Reserve estimates is a fundamental difference between Mineral Resources and Ore Reserves and this must be borne in mind and caution exercised if attempting to draw conclusions from a comparison of the two.
- When estimating Ore Reserves, particularly for underground mining methods, difficulties can arise when it is necessary for practical reasons to include Inferred Resources in the practical mining outlines around Indicated or Measured Mineral Resources. Difficulties can also occur when dilution includes metal values, which are not part of the Mineral Resource model. These problems can mostly be addressed by preparing the Mineral Resource model so as to avoid these difficulties. However, the Ore Reserve is intended to reflect the tonnage and grade of material to be delivered to the processing plant and the Competent Person must make judgements based on the principles of transparency and materiality in preparing and classifying the Mineral Reserve estimate.

- The entire Reserve, including diluting materials, must be assessed as economic using reasonably assumed commodity prices and costs. The JORC Code provides no fixed definition for the term ‘economically mineable’ and does not specify a basis for estimating commodity prices. The reasonableness of commodity prices should be assessed in the context of the period of time over which the Ore Reserves are to be mined.

Mineral processing recovery is not included in the estimation of Ore Reserves, except in so far as process recovery is used to assist in identifying cut-off grades and in the overall economic analysis of the Ore Reserve. There are exceptions to this in the case of estimating marketable coal reserves and when estimating reserves for some industrial minerals.

REPORTING OF ORE RESERVES

The JORC Code provides detailed guidelines for the public reporting of Ore Reserves and it is recommended that mine managers become familiar with this document. The following points are not intended to supplement the Code, but highlight some of the key requirements of the Code and suggest a number of good practices relating to transparency:

- The JORC Code requires that where estimates for both Mineral Resources and Ore Reserves are reported, a clarifying statement must be included that clearly indicates whether Mineral Reserves are part of the Mineral Resource or that they have been removed from the Mineral Resource. A single form of reporting should be used in a report. The Code suggests the following forms of clarifying statements:

The Measured and Indicated Mineral Resources are inclusive of those Mineral Resources modified to produce the Ore Reserves

or:

The Measured and Indicated Mineral Resources are additional to the Ore Reserves.

- Mineral Resources and Ore Reserves are fundamentally different and must not be aggregated to report a single combined figure. To do so would be potentially misleading.
- Proved and Probable Ore Reserves should not be reported in a combined form unless details of the individual categories are also provided.
- Mineral Resources and Ore Reserves must not be reported in terms of contained metal or mineral content unless the corresponding grades and mining, mineral processing and metallurgical recoveries are also presented.
- Reports should maintain internal consistency in regard to reporting units for both Mineral Resources and Ore Reserves. The mixing of metric and imperial units (eg oz/tonne) should be avoided.
- When reporting an Ore Reserve mineable by open pit methods, the waste-to-ore ratio should be disclosed.
- Reporting of mineral or metal equivalence or net smelter return values should be avoided unless appropriate correlation formulae, including assumed metal prices, metallurgical recoveries, comparative smelter charges, likely losses, payable metals, etc are included.
- ‘Marketable coal reserves’, representing beneficiated or otherwise enhanced coal product, where modifications due to mining, dilution and processing have been considered, may be publicly reported in conjunction with, but not instead of, reports of coal reserves. The basis of the predicted yield to achieve marketable coal reserves should be stated.

6.1.3 An overview of Mineral Resource estimation

INTRODUCTION

Scope and goals

The goal of this section is to provide insight into the most important issues affecting the quality of Mineral Resource estimates and the way in which these issues are handled with modern Mineral Resource estimation methods. The discussion focuses on the application of Mineral Resource modelling methods to the estimation of resources in advanced exploration and mining projects. It does not necessarily apply to the problem of Mineral Resource estimation for mineral projects at earlier stages of exploration where other less complex approaches may be applicable.

The purpose of Mineral Resource modelling depends on the stage of development a mineral project has reached along a path that stretches from discovery through exploration to feasibility, development and mining. Discovery of a potentially economic Mineral Resource usually occurs when a small number of drill hole intersections within a spatially confined volume indicate significant mineralisation of a similar type or style suggesting some continuity of the mineralisation among the intersections. From discovery, the mineral project may progress along a path of more intense exploration, incorporating the results of sampling and assaying of the drill hole and surface and other samples, geological logging of core and rock chip sampling and interpretation of the geological setting hosting the mineralisation. During this process, estimates of the potential Mineral Resource provide part of the basis for decisions to continue with further exploration and possible development or to abandon the project. Ultimately, a successful exploration project will reach prefeasibility, at which point it may be seriously considered as a potential mining project.

From the point in time at which a program of quasi-regular drilling and sampling of the mineral deposit has commenced through to the end of mine life, the primary purpose of Mineral Resource modelling is to provide a sound basis for medium- to long-term mine planning of the exploitation of the Mineral Resource. Medium- to long-term planning usually means the period from three to six months ahead of production to the end of mine life, while short-term planning is handled with grade control modelling. During this period, various proportions of the Mineral Resource estimates will be classified as Measured, Indicated and Inferred to reflect the confidence in the estimates of those proportions. This confidence is generally used to characterise the relative risk associated with their inclusion in the mine plan.

Overview of methods

Methods used to estimate the tonnage and grade of Mineral Resources have varied over time in response to a range of technological, economic and political factors. From a technology perspective, the most significant development of the last 40 years affecting the way in which Mineral Resources are estimated has been the computer and in particular, the personal computer. Today, almost all Mineral Resource estimation is performed using micro-computers running relatively sophisticated programs based on applications of technology developed within the past 20 to 30 years, with some emphasis on well tried and tested methods.

The development of modern estimation methods and associated computer programs that are used to estimate Mineral Resources in deposits is a response to the accelerating demand for

minerals and metals of increasing variety, which over time drives the grade of economic ores lower. In some cases, it is also a response to the increasing technical problems of estimating the resources for specific types of minerals, such as gold, to a sufficient level of precision and accuracy to make economic recovery at very low concentrations possible. In other cases, such as coal and iron ore, where impurities and product quality control are important issues, spatial simulation methods have a useful role to play in the estimation of the Mineral Resource.

Pre-computer methods

Prior to the advent of the modern computer, manual methods of resource estimation were used. While the author has very limited experience of applying these methods, the common practice was to develop two-dimensional polygons (or areas of influence) either on level plans or on drill sections based on the application of a potentially economic cut-off grade to the grades of drill hole samples or composites. Polygons were then extended half of the distance to the nearest drill sections or plans to define the volume of influence of each polygon. The grade of the material within the three-dimensional polyhedron was calculated as the average grade of the samples falling within the polyhedron.

Many of the modern mining software packages provide tools to emulate the manual modelling practices of the pre-computer period. The modern terminology for the sectional and bench polygons is 3D shapes, or solids wire frames. The criteria used to construct these modern 3D shapes are similar to those used in the past: cut-off grades and interpreted geology. It is presently common practice to use such 3D shapes or interpretations to constrain the way in which Mineral Resource estimates are generated.

Computers and block models

The significant departure with the past pre-computer practice of Mineral Resource estimation arises with the methods used to estimate the local grade of material within the body of mineralisation. Whereas manual averaging of large numbers of drill hole grades was an arduous task and a single computation of a Mineral Resource might take days to weeks, such computations are essentially instantaneous using computers. The ease of precise computation using computers, coupled with high-quality 3D graphics, has allowed the introduction of more sophisticated analytical techniques to describe the continuity of the grade of mineralisation with consequent improvement in the quality of grade estimates. With computer-based methods, the mineral deposit is described by a model of regularly shaped rectangular blocks, commonly referred to as a block model. The block dimensions are usually chosen to be compatible with the drill hole spacing and the scale of the mineralised structures in the deposit. However, some resource modelling software packages permit the use of a range of blocks sizes, which allow more compatibility of the block model and the interpreted 3D shapes mentioned above.

The major mining software packages provide a number of methods to estimate the grades of individual blocks within a block model. These estimation methods usually require an input file of the drill hole composite grades and a set of input parameters, including the grade continuity function and search neighbourhood parameters. The search neighbourhood parameters define the volume around each block from which the composite data to be used in the estimation of the block grade may be drawn. The minimum and maximum number of composites to be used in the estimation of the block may also be defined. In some instances, the search parameters may also constrain the spatial distribution of the neighbourhood composites and the maximum number of composites from any particular hole that may be used.

Block grade estimation methods in modern Mineral Resource modelling software vary from equal weighted averaging of local sample grades through linear weighting methods, such as inverse distance methods (IDW) and ordinary kriging (OK) to more complex methods, such as multiple indicator kriging (MIK), uniform conditioning (UC) and conditional simulation (CS) (Deutsch and Journel, 1998; Isaaks and Srivastava, 1989; Wackernagel, 2003). Strictly speaking, CS in its various forms is not an estimation technique. However, the average of say 50 to 100 simulated values of a block grade may be considered similar to an estimate derived by some of the other estimation methods mentioned.

With a variety of estimation methodologies available to the modeller, it seems logical to ask ‘Which method is the best?’ There is of course, no best method for all situations. Mineral Resource estimation is a risk mitigation exercise that draws on the technical skills and the working experience of the modeller to understand the risk-generating characteristics of different types and styles of mineralisation. The resource modeller draws on the occurrence of certain common risk-generating and risk-mitigating properties among mineral deposits and modelling methods to decide which method is appropriate to estimate the resource in any particular situation.

RISK GENERATING ASPECTS OF MINERALISATION, SAMPLING AND MINING

The most important characteristics of mineralisation, sampling and mining that increase the uncertainty in the estimates of local and global resources are: the quality and spatial distribution of the drill hole samples, the complexity of the ore geometry, the cut-off grade and the presence of extreme grades in the sample data set. The differences between the spatial and statistical properties of samples, which represent the most common scale of observation, and blocks that represent the most common scale of prediction, may also introduce a significant level of risk for some approaches to Mineral Resource estimation.

Drill hole samples and the quality of resource estimates

Regardless of the method used to estimate resources, the quality of the estimates depends directly on the number, quality and distribution of drill hole samples taken from within the volume of potentially ore-bearing mineralisation. The most appropriate spatial distribution of these samples is usually a random stratified grid, but there are often good reasons why such a pattern may not be achievable: access problems due to extreme topography for example. During early exploration drilling of a potential mineral project, it is usual for drilling to become clustered in the more promising areas, but once the broad scale features of the potentially economic mineralisation are reasonably established, a quasi-regular pattern of drilling and sampling is the most beneficial for the estimation of the Mineral Resources.

The relationship between the amount of drilling (drilling costs) and the quality of global Mineral Resource estimates at different cut-off grades is illustrated in Figure 6.1.4. The figure indicates that the greatest benefit from drilling and sampling occurs when the drill hole spacing is still large relative to the underlying continuity of the mineralisation. The benefit diminishes as the drill hole spacing decreases and the number of samples increases. This diminishing return on drilling expenditure occurs because of the increasing redundancy of both geological and grade information among drill hole samples as the hole spacing decreases.

Figure 6.1.4 also indicates that the quality of global estimates is related to the cut-off grade used to define them. For the same amount of drilling, the resource estimate defined at a higher cut-off grade is inferior in quality to that defined at a lower cut-off grade. The degree of inferiority can depend on the nature of the mineralisation. The phrase ‘This orebody has a natural cut-off grade of ...’ usually refers to a situation where there is rapid

FIG 6.1.4 - Quality of resource estimates in relation to drill hole spacing and cut-off grade.

change in grade from essentially completely barren material to material of significant grade over a short distance relative to the length of the mineralised intersections. Some styles of structurally controlled mineralisation associated with massive sulfides may exhibit this kind of robustness over small cut-off ranges but it is rarely associated with larger-scale, more disseminated styles of mineralisation.

Although Figure 6.1.4 refers specifically to *global* estimates of resources, it might equally well be used to discuss the quality of local block estimates with an appropriate change to much fewer samples on the bottom axis. Consideration of this figure at global and local scales offers some insight into the fundamental difference between the Inferred Resource classification and the Indicated and Measured classification. Indicated and Measured Mineral Resource estimates may not be significantly more reliable than Inferred estimates at the global scale because of the problem of information redundancy at that scale. However, they are much more reliable than Inferred estimates at the local block scale as a result of having sufficient drilling to establish the continuity of the mineralisation at the local scale. It is this knowledge of the continuity of the mineralisation at the local scale, together with closer sample spacing, that makes Measured and Indicated Mineral Resource estimates suitable for reserve estimation, mine planning and medium- to long-term scheduling.

Cut-off grade and ore geometry

Ore is that part of the mineralisation that can be mined and processed for profit, ie it is based on mineability and economic criteria and may or may not correspond with mappable geological features of the mineralisation. The complexity of the ore geometry and the cut-off grade tend to be closely related in the sense that as the cut-off grade used to define ore is increased, the proportion of the mineralisation above the cut-off grade (ore) decreases and the spatial distribution of the ore tends to become more geometrically complex and more difficult to estimate. At lower cut-off grades, where larger proportions of the mineralisation are ore, the uncertainties associated with estimating the location and grade of the ore are smaller.

These particular characteristics of mineralisation are closely related to the statistical notion of 'proportional effect' and the geostatistical notion of 'spatial continuity'. The proportional effect describes the relationship between the local average grade and the local variability of grade in a mineral deposit. This relationship is commonly both direct and strong, ie in higher grade areas the grade tends to be more variable at any reasonable scale of observation (samples or blocks). Spatial continuity describes the statistical correlation between the grades of samples for any spatial separation vector in the mineralisation. This continuity is often spatially anisotropic, being stronger in some directions, and also grade dependent, ie the continuity tends to be stronger around the median of the sample grades and weaker among relatively high sample grades in many mineral deposits.

Influence of extreme sample grades

An extreme sample grade is one that departs significantly from the main statistical grouping of the grades within a population of mineralised samples. Extreme sample grades can arise in many situations where the ore-bearing minerals change their form, eg ex-solution of native silver or silver sulfides in a lead-silver deposit where most of the silver occurs within the galena lattice; but it is more commonly associated with base and precious metal deposits where the element of interest occurs as the native metal, ie gold, platinum, supergene native copper. In some applications of statistical analysis, an extreme sample grade may be called an 'outlier' but in the context of sample grades in mineral deposits, 'extreme' sample grade is a more appropriate description. The term 'extreme' does not imply that the sample grade is in error or in some way inappropriate in the context of the mineralisation from which it was extracted.

Whether the presence of a very small proportion of extreme sample grades in a sample data set is a problem in Mineral Resource estimation depends on how extreme the sample grades are relative to the main body of sample grades, and what proportion of the mineralisation will be recovered as ore. In a porphyry copper deposit, where a very high proportion of the sampled mineralisation is usually recovered as ore, the presence of a small proportion of very high copper grades among the samples would generally have no measurable impact on ore definition or estimates of the grade of the ore when these high-grade samples are included in the modelling process. This is because the amount of copper metal contained in the high-grade samples is a very small proportion of the total copper metal contained in all of the samples that fall within the ore.

An entirely different situation occurs in many precious metal deposits where commonly a high proportion of the samples contain almost no metal, while one or two samples may contain as much as 50 per cent of the metal in all of the samples with sample grades ranging over two to perhaps five orders of magnitude. In this case, the impact of the extreme values on both the local and global estimates of tonnage and grade can be overwhelming and must be given careful consideration in the modelling. The sample statistic often used to characterise the problem of sensitivity to extreme sample grades is the coefficient of variation (CV) of the sample grades and is calculated as the standard deviation of the sample grades divided by their mean grade. Figure 6.1.5 provides a graphical view of the relationship between the proportion of ore in a deposit and the CV of the sample grades. Essentially, as the CV increases above three, the element of interest, for example gold, becomes gradually concentrated in a decreasingly smaller volume of the rock within the mineralised envelope. As a consequence, efficient exploitation requires that decreasingly smaller volumes can be economically processed as ore.

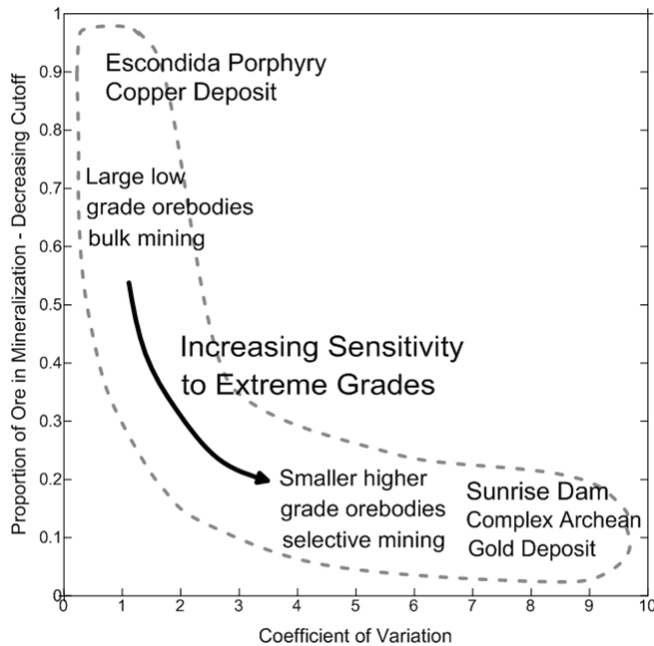


FIG 6.1.5 - Sensitivity of resource estimates to extreme sample grades.

Spatial and statistical properties of sample and block attributes

One of the most important features of geological and grade information to appreciate in relation to resource estimation is their dependence on the scale of observation. Almost all geological and grade observations in a body of mineralisation are made at the scale of samples: core samples, channel samples, etc. Some geologic information, such as face mapping, may be gathered at larger scales but these situations usually have local rather than global significance.

In almost all mines, ore is defined on mineable units or blocks that are hundreds to thousands of times larger in volume than drill hole and other types of samples. As a consequence of these differences in the scale of observation and the natural variation of geological and grade attributes in the mineralisation, the geologic and grade attributes of samples and blocks have significantly different statistical characteristics (Parker, 1979). The contour maps of samples and 10 m block grades shown in Figure 6.1.6 illustrate the differences in the spatial character of sample and block observations. Figure 6.1.7 compares the cumulative histograms of the sample and block data of Figure 6.1.6: if the cumulative histograms were the same, the data would plot along the straight line.

When the spatial and statistical properties of samples and blocks are compared over the same volume of mineralisation, the only property they have in common is the average or mean grade. The frequency statistics, histograms and spatial continuity characteristics of block grades are generally different from those of samples, with the magnitude of the differences related directly to the size of the block. Any arbitrarily selected block with an average grade exceeding a particular cut-off grade will almost certainly contain some proportion of samples with grades less than that cut-off.

As a consequence of these differences in statistical properties and the fact that the resource in a mineral deposit depends directly on the properties of blocks rather than samples, the direct use of sample attributes as estimates of block attributes can lead to significant errors in

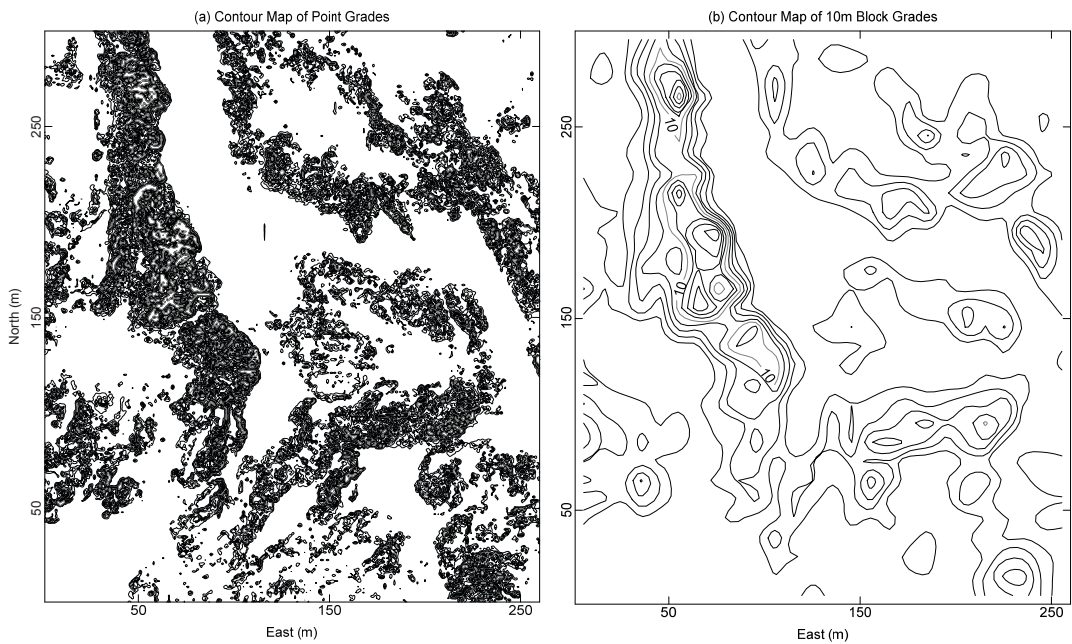


FIG 6.1.6 - Contour maps of the sample and block observations of the same grades.

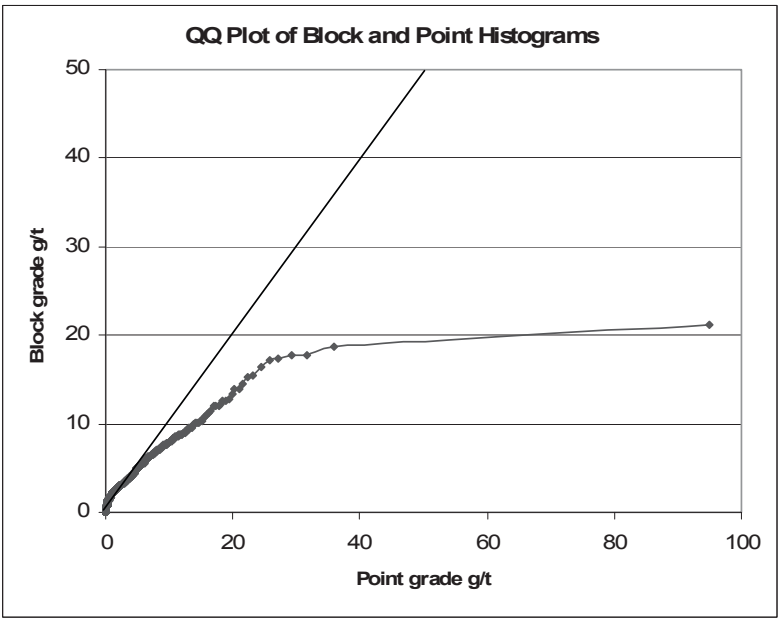


FIG 6.1.7 - Comparison of the cumulative histograms of sample and block grades.

the estimates of Mineral Resources in many types of deposits. This problem of scale has least impact in mineralisation, exhibiting very little variation in the grade ($CV < 0.2$), or where reliable visual control of mappable geology can be used to define the ore and thus, a cut-off grade is unnecessary. Such situations are rare.

The difference between the properties of sample and block attributes has important implications for Mineral Resource estimates where interpreted geologic models constructed from sample observations are used to constrain the way local estimation of block grades

is performed. Significant overestimation of Mineral Resource grade is a common outcome (Schofield, 2011).

RESOURCE ESTIMATION METHODS

Having outlined what are considered to be a number of the most important issues affecting the quality of resource estimates in a wide range of mineral deposits, it is now convenient to discuss methods of resource modelling in terms of the way they handle the impact of these issues on the estimates that are generated. More complex modelling methods involving larger numbers of parameters are often required to handle the increasing complexity and uncertainty associated with higher cut-off grades and higher CVs. This increasing complexity in the modelling methods is broadly characterised by the change from linear estimation methods (IDW and OK) to non-linear estimation (MIK, UC) and further to conditional simulation methods (CS) which, theoretically, have application to a more general range of resource modelling and optimisation problems.

Linear and non-linear estimation of block attributes

Figure 6.1.8 shows a two-dimensional example of the block estimation problem. The blocks to be estimated are centred on a regular grid of 10 m² with the current block shown in solid outline. The drill hole sample locations in the neighbourhood are shown as crosses with the grade displayed above the cross. The search neighbourhood for the current block is shown as a dashed circle. In this relatively simple scenario, the 14 samples falling within the dashed circle would be used to estimate the grade of the current block.

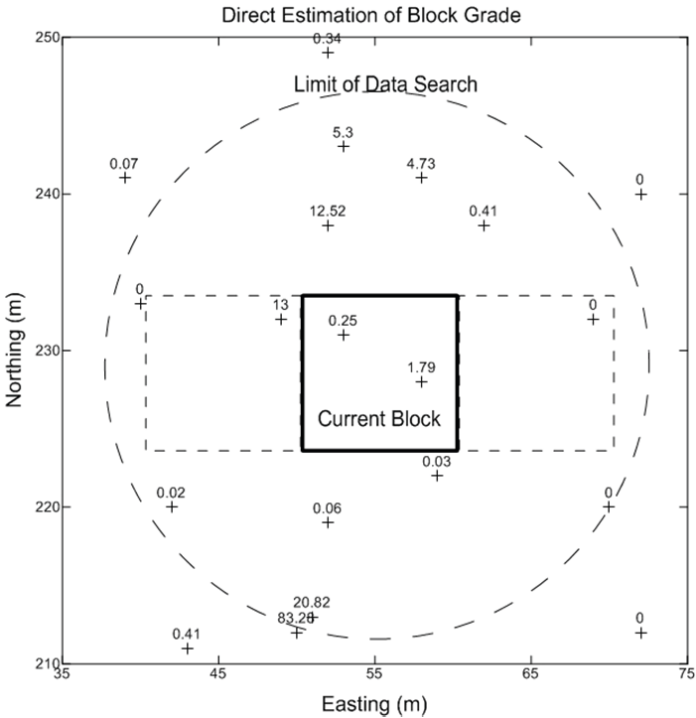


FIG 6.1.8 - Direct estimation of block grades.

All block estimation methods use a model of the spatial relationship among the grades of the samples and the grade of the block to calculate the sample weights that are used to

estimate the block grade as a weighted average of the 14 sample grades in the following equation:

$$g^*(u_0) = \sum_{i=1}^{14} w_i \cdot g(x_i)$$

where:

$g^*(u_0)$ is the estimate of the block grade

$g(x_i)$ are the neighbourhood sample grades

w_i are the weights generated by the particular estimation method

Different estimation methods may generate different weights for the informing samples, first because they use different models of the grade continuity and second because some methods make better use of the spatial distribution of sample information than others. Modelling methods that estimate the block grade directly as a weighted average of the sample grades are generally referred to as linear estimation methods. The IDW method and OK methods fall within this category of estimation method.

The non-linear estimation methods, such as MIK and Gaussian-related kriging methods (multi-Gaussian kriging, Gaussian disjunctive kriging), use a similar weighted averaging approach to that described above. However, unlike the linear methods, they do not estimate the block grade directly. The goal of non-linear methods is to estimate a non-linear function of the block grade, usually the cumulative histogram. With MIK, this is achieved by first creating indicator data for a number of grade thresholds on the cumulative histogram of sample grades. Figure 6.1.9 shows the same block and data configuration as Figure 6.1.8 but with indicator data for the threshold of 1.0 defined according to the rule:

$$i(x; 1.0) = \begin{cases} 1 & \text{if } g(x) \leq 1.0 \\ 0 & \text{otherwise} \end{cases}$$

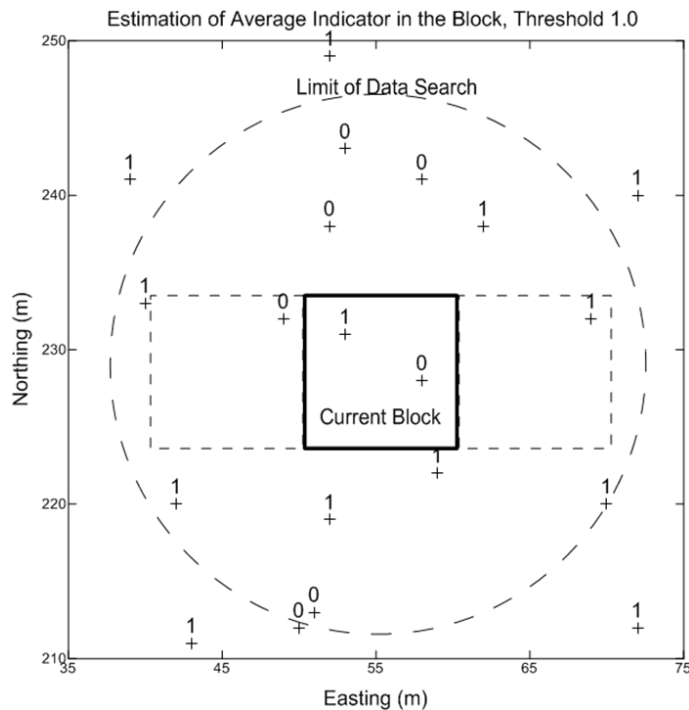


FIG 6.1.9 - Direct estimation of the average indicator $I(1.0)$ in the block.

The MIK estimate at the 1.0 threshold is a weighted average of the indicator data (0's and 1's) defined for that threshold within the search neighbourhood. The MIK estimate at a particular grade threshold (1.0 in this case) may be interpreted as the probability that the population of sample grades within the block will not exceed that threshold, or the proportion of samples within the block with grades not exceeding that threshold.

Other non-linear methods such as the Gaussian methods mentioned above make use of appropriate non-linear transformations of the histogram of sample grades to estimate, either directly or indirectly, the cumulative histogram of sample grades within the block. The method of uniform conditioning falls somewhere between the linear and non-linear categories in that the OK estimate and variance are used to approximate the conditional cumulative histogram of sample grades within the large block.

Linear estimation methods

Inverse distance weighting and nearest neighbour method

In determining the weight to be applied to a particular variable in estimation, IDW methods assume a grade continuity function that is related to the inverse of the distance from the sample to the block taken to some power p :

$$w_i = \frac{1/d_i^p}{\sum_{j=1}^n 1/d_j^p}$$

where:

d_i is the distance between the i^{th} sample and the current block

For each block estimate, the sample weights are scaled to sum to 1.0, a condition which reasonably ensures that the block estimates are globally unbiased in relation to the average grade of the samples. The choice of P is arbitrary and often based on the experience of the user. For values of $P > 2.0$, in an estimation neighbourhood containing more than one sample, the weight on the sample nearest to the block grows rapidly: for $P \geq 3$, the inverse distance weighting method effectively becomes a polygonal or nearest neighbour estimation method.

Ordinary kriging

The OK estimation method differs from IDW methods in a number of important ways, which make the method more difficult to appreciate, but which improves the quality of the estimates and allows customisation of the approach to particular estimation problems:

- The OK method is based on the widely-used method of least squares regression. The OK sample weights minimise the variance of the estimation error, ie:

$$\text{Var}\{g^*(u_0) - (g(u_0))\}$$

where:

$g(u_0)$ is the true unknown grade at location u_0

- The OK method uses a model of the spatial continuity of the sample grades that is based on the actual sample values, ie the variogram model. This model $\gamma(\underline{h})$ describes the spatial statistical correlation between pairs of samples separated by the spatial vector $(\underline{h})$. The variogram model accounts for important properties of the spatial continuity, such as random sampling error, which is incorporated in the nugget variance, and directional anisotropy, which may be associated with stronger structural control of mineralisation

in some directions. The magnitude of the nugget and the strength of the directional anisotropy are the most important parameters of the variogram model influencing the kriging estimate. Essentially, the variogram model is a function that transforms physical (Euclidian) distances into variogram distances that reflect the strength of the spatial correlation between the grades of pairs of samples separated by a spatial vector ($\underline{h}$).

- The sample weights that arise as the solution to the kriging equations take into account the variogram distances between the samples and the block as well as the variogram distances among the informing samples. These inter-sample correlations help to account for information redundancy in the informing data due to local clustering and screening of some samples by others.

Like the IDW approach, the OK sample weights are constrained to sum to 1.0 to achieve globally unbiased estimates of block grade.

With some qualifications that are beyond the scope of this presentation, the properties of OK described above apply to all forms of linear and non-linear kriging estimators. Most applications of MİK are simply OK with indicator data and Gaussian kriging in its various forms may be considered as ordinary kriging of Gaussian data.

The spatial continuity function used in kriging

The spatial continuity or variogram function $\gamma(\underline{h})$ is one of the most important parameters in all kriging estimation methods. A detailed discussion of its derivation can be found in the references but it may be useful for the reader to appreciate the scope and power of this function to represent the relative contributions to the grade continuity of a number of different styles of mineralisation that may be present in the sample values.

Figure 6.1.10 presents contour maps of the continuity created by three mineralisations with directional anisotropies that are not orthogonal and varying in their relative influence. In Figure 6.1.10a, the dominant trends are north-north-west and north-north-east, while in Figure 6.1.10b, the north-north-east trend is stronger and the north-north-west trend is diminished relative to the more isotropic west-north-west trend.

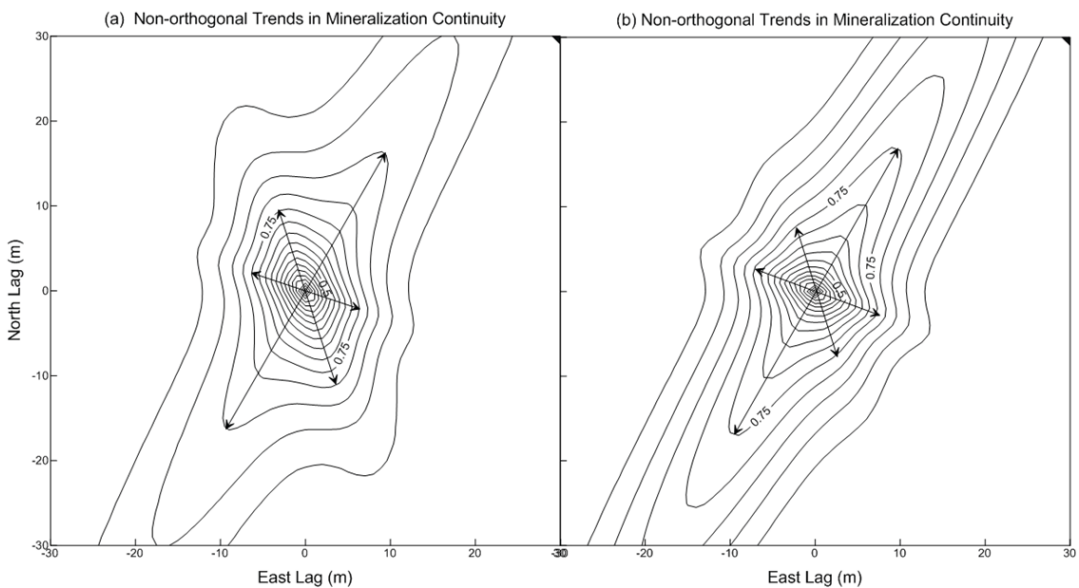


FIG 6.1.10 - Two-dimensional variogram models with complex patterns of continuity.

These figures highlight another important feature of the spatial continuity of mineral grades in many mineral deposits: the anisotropic properties of continuity are a function of scale. In both figures, at short lags of less than 10 m, the pattern of continuity is nearly isotropic, while at larger lags of 20 to 30 m, the anisotropy appears much stronger. In the analysis of real sample data sets, these larger-scale anisotropies are usually easy to recognise with simple grade contouring, and tend to most strongly influence our interpretation of the spatial properties of the mineralisation. However, it is the pattern of continuity at the smaller lags that has most influence on the estimation of the block grade.

In the application of OK, the variogram model derived from the actual sample grades is the appropriate continuity function. When using the non-linear estimation methods, the appropriate variogram model is that derived from the transformed sample grades. The application of the MIK method usually requires the creation of indicator data for a number of grade thresholds, gt_k , $k = 1, K$, which span the histogram of sample grades. For each gt_k , a unique set of indicator data is created according to the rule:

$$i(x; gt_k) = \begin{cases} 1 & \text{if } g(x) \leq gt_k \\ 0 & \text{otherwise} \end{cases}$$

and characterised by a unique spatial continuity model, which depends on the grade threshold. Indicator variogram analysis of sample data sets from mineral deposits demonstrates that the spatial continuity is a function of grade and usually decreases with increasing grade threshold above the median of the sample grades. The density and range of contours in the two maps in Figure 6.1.11 illustrate the stronger indicator continuity at the median threshold compared to that at the 90th percentile of lead grade in a massive sulfide body.

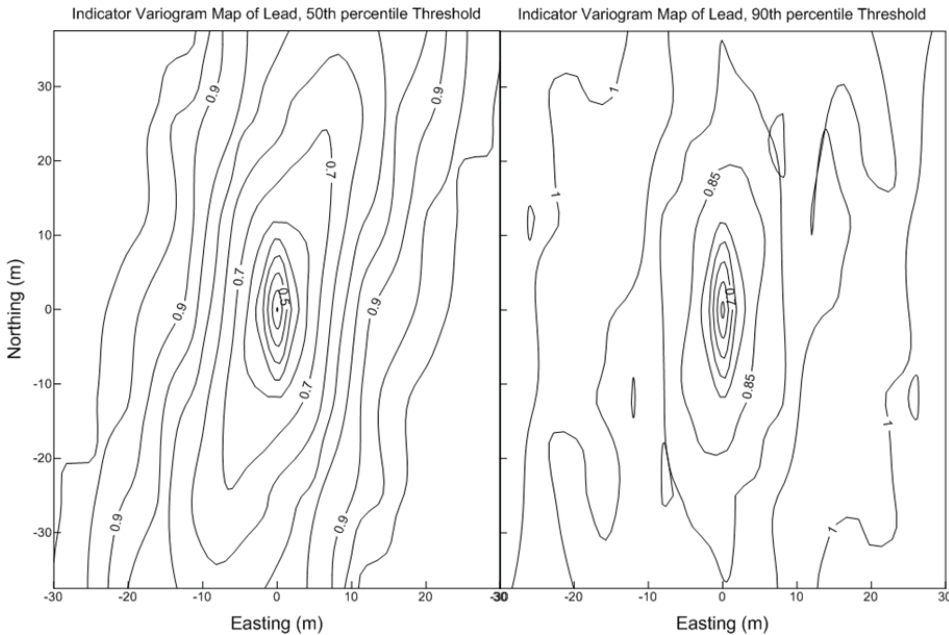


FIG 6.1.11 - Indicator variogram maps of lead, median and 90th percentile thresholds.

The indicator variograms and variograms of other non-linear transforms of grade usually provide a more detailed and robust description of the underlying spatial continuity of the sample grades, in large part because the statistics of the transformed data are less sensitive

to the presence of extreme sample grades. For most data sets with a CV greater than two, the presence of extreme grades tends to mask a significant component of non-linear continuity among the sample grades.

Non-linear estimation and simulation methods

Non-linear estimation

Non-linear estimation can reasonably be thought of as linear estimation using sample values that are some non-linear transformation of the sample grades, ie the indicator transformation as discussed above. In most common applications of MIK, the estimation process is simply an ordinary kriging of indicator data (1's and 0's).

The difficulty with non-linear methods arises in the understanding, interpretation and post-estimation processing of the kriging estimates. Usually, the direct goal of the non-linear methods is an estimate of the conditional histogram of sample grades within the target volume or block. This is illustrated in Figure 6.1.9 where the MIK estimate for the grade threshold of 1.0 can be interpreted as the proportion of samples within the block with grades less than 1.0 g/t. In this case, if further MIK estimates are made for an appropriate set of grade thresholds, the set of estimates may be interpreted as a conditional cumulative histogram of sample grades within the block. Using an appropriate choice of mean grade statistics for each of the indicator classes created by the indicator thresholds based on the sample grades chosen for modelling, the grade of the block may be estimated as the average of the indicator class means weighted by the estimated indicator class proportions obtained from the MIK estimates. This estimated block grade (also called the E-type estimate) is the MIK equivalent of the OK estimate of block grade.

The non-linear estimation methods, when used appropriately, have several important advantages over linear methods in tackling some of the risk-generating factors of resource estimation discussed above.

Conditional simulation

The first property of OK estimates discussed above (minimum estimation variance) endows the kriging estimates derived from a particular data set and a particular variogram model, with a unique character. They are the only set of estimates that satisfy this minimum variance property for that particular data set and variogram model. However, minimum variance estimation comes with a cost: the contour map of kriging estimates of block grade tends to be smoother than the contour map of underlying block true grades. Areas of higher-than-average true grade tend to be underestimated in grade and areas of lower-than-average true grade tend to be overestimated. The amount of smoothing present in OK estimates is a function of the spatial continuity, in particular the relative magnitude of the nugget variance, and the sampling spacing relative to the volume being estimated.

If one of the problems to be addressed in the evaluation of a mineral deposit is a consequence of the variability of a particular attribute, eg impurities like alumina or phosphorus in iron deposits or sulfur in coal, conditional simulation can be a useful modelling tool. It is also useful if the attribute of interest is of high value and confined to a small fraction of the rock as in many precious metal deposits. In these situations, the actual spatial variation in these attributes is not accurately mapped in the OK estimates and this can have a significant impact on blending processes and on ore-waste decisions in very high-grade areas.

Figure 6.1.12 presents a grade profile comparing true block grades with the OK estimates and three sets of simulated block grades generated from the same set of informing samples

FIG 6.1.12 - Profile of actual, estimated and simulated block grades.

on a regular 10 m pattern. The profile of OK estimates is clearly less variable than either the profile of true grades or the simulated grades and this is most obvious where the true grades tend to be higher. If the goal of modelling depended on the frequency with which the grade exceeds a particular threshold, say seven in this case, the results provided by the OK estimates would be unreliable.

The value of conditional simulation and optimisation of ore selection in grade control is now well established and has led to very significant improvements in ore selection, head grade prediction and stockpile management. The application of large-scale simulation to the modelling of Mineral Resources in entire orebodies is still at the development stage and its full potential in this area is yet to be realised.

PRACTICAL AND IMPLEMENTATION ISSUES

Data quality

The importance of data quality in resource estimation cannot be over-emphasised. Errors in sample location (drill hole collar and downhole surveying), sample definition (composite length), sample processing (crushing and splitting) and sample measurement (assayed grade, bulk density, etc) all detract from the quality of the estimates generated by any resource estimation method. Sampling errors are commonly the source of mine reconciliation problems. The establishment of an appropriate system for processing of drill hole samples, as well as routine monitoring of the sample quality produced by that system, is the only way to avoid time-consuming and costly investigations of data quality when production problems appear.

Data search strategy in estimation

Data searching is a very important practical consideration in any resource modelling process. It determines which samples will be used to estimate the grade of a particular block that occurs at the centre of the search neighbourhood. A simple two-dimensional example

of the data search neighbourhood is shown by the circle in Figure 6.1.8 inside which some 14 samples are found. In a real three-dimensional situation, there are a number of issues that combine to make the problem of data selection more complex:

- *Data clustering* – three-dimensional data tends to be variably clustered, firstly because the sample interval in the downhole direction is much smaller than in other directions. Difficulties with both surface and underground access to drilling sites compound these problems. Segment or octant search properties are often used to diminish the effects of local data clustering on the kriging estimate.
- *Block dimensions* – the size and shape of the volume being estimated affects the shape and size of the search neighbourhood. The search neighbourhood is usually defined as an ellipsoid whose eccentricity depends primarily on the average drill hole spacing. For obvious reasons, the search ellipsoid must not intersect the block being estimated. This can be a problem when estimating large rectangular blocks using anisotropic, rotated search ellipsoids (see Figure 6.1.13).
- *Search dimensions* – an ellipsoidal search in three dimensions is usually defined by three search radii and a number of three-dimensional rotations, which allow the orientation of the search ellipsoid with respect to drill hole directions and trends in the mineralisation. Taking into account the problems of access and resultant clustering discussed above, the most important determinant of the search radii is the underlying drill hole spacing, which usually has some quasi-regularity to it, eg regular drill section spacing, etc. The search radii should be large enough to satisfy reasonable minimum data criteria but no larger. Large search radii increase the risk that samples unrelated to the current block grade will be used to influence the estimate.
- *Estimation method and minimum data* – in general, non-linear methods are used to estimate more complex local functions of the sample data and achieve better results when more data are used, provided of course those data are relevant to the estimate being generated.

FIG 6.1.13 - Rotated search neighbourhood with a large block.

- *Mineral Resource classification* – it is common to use the drill hole spacing in the neighbourhood of a block estimate as an important factor in the Mineral Resource classification of the block estimate. Establishing geologic and grade continuity through more closely-spaced sampling is the most important factor in the JORC Mineral Resource classification scheme. In practice, an initial search with small search radii is used to establish estimates with the highest confidence (Measured), after which the search radii are expanded by small increments to generate estimates of lesser confidence (Indicated and Inferred). Another approach is to predefine areas of higher and lower confidence estimates based on visual inspection of the drill hole spacing over the deposit. This approach usually leads to more continuous areas of higher and lower confidence estimates, which some practitioners consider an advantage.

There is a widely-held view that the range of the variogram model can be used to determine the dimension of the search radii. This view is often used to justify very large search radii and block estimates located at large distances from informing samples, eg estimated grades of small blocks within very detailed wire frames based on very few drill hole samples within the wire frames. There are good reasons why this practice should be avoided. Firstly, variogram models often have multiple ranges, the longest of which are usually associated with broad scale trends that have no influence on the quality of the local estimate. Secondly, as discussed above, the further a sample is from the block being estimated, the more likely it is to be unrelated to the grade at that block. It is almost always better to generate an estimate using fewer samples closer to the point of estimation than to use more samples from further away.

Modern Mineral Resource modelling software packages may allow the user a large number of search constraints beyond the simple ideas of an ellipsoidal search with minimum and maximum data constraints as well as segmented or octant constraints to mitigate the effects of local clustering. For example, some packages allow the minimum number of drill holes to be defined as well as the maximum number of samples per hole. All of these additional constraints add to the complexity of the searching algorithm and the interpretation of the result without generally improving the quality of the block estimate.

Estimation methods and block models

The choice of block size to use in Mineral Resource modelling is related to the nature of the mineralisation and the scale of selection envisioned in mining the deposit. As discussed above and in relation to Figure 6.1.4, the degree of selectivity required in mining is often related to the scale of variation of the sample grades in the deposit.

High variation in grade, as characterised by a coefficient of variation in excess of two, would normally lead to mining on relatively small benches of less than 5 m with equipment able to mine to a minimum mining width of around 4 to 10 m. In this kind of deposit, Mineral Resource drill hole spacing would normally range from 20 to 50 m depending on the size of the deposit. Some large deposits in excess of, say, 50 million tonnes, with a broad surface footprint may be drilled out at a broader spacing compared to smaller deposits without any significant increase in the mine planning and scheduling risks.

In deposits of this kind where ore selection at a relatively small scale is envisioned, recoverable Mineral Resource estimation through the use of MIK and UC is an appropriate method of estimation with a basic block or panel dimension equal to the average horizontal drill hole spacing. The panel should comprise at least 20 of the mining units that would be the basis of ore selection in production. A two-dimensional sectional view of this is shown in Figure 6.1.13, where the bigger blocks are subdivided into a number of smaller, mineable

blocks. In this case, the search is rotated so that the longer axis is approximately parallel to the main continuity in the mineralisation (plunging at around 50 degrees to the north) and the radii must be large to envelope the bigger blocks and sufficient neighbouring samples.

SUMMARY

Modern Mineral Resource estimation most commonly relies on the use of computer-generated block models constructed using geostatistical methods like ordinary kriging. Traditional methods such as nearest neighbour (polygonal) methods are no longer considered reliable for most applications.

Mineral Resource modelling is a risk mitigation process that draws on the skill and experience of the modeller to choose and implement an appropriate approach for the modelling and estimation problem at hand. The main risk-generating factors that influence the quality of resource estimates are:

- *The number, quality and spatial distribution of the drill hole samples* – more good-quality samples generally lead to better estimates of block grade. Poor quality samples generally lead to poor estimates and potentially unquantifiable risks.
- *The complexity of ore geometry and the cut-off grade* – ore geometry is generally more spatially complex at higher cut-off grades as a result of more complex host geology and structural deformation.
- *The influence of samples with extreme grades* – as a general rule, the more concentrated the metal of interest is within a small proportion of the samples, the greater the risk associated with Mineral Resource estimates. The coefficient of variation (CV) of the sample grades provides a useful yardstick for assessing this risk.
- *The spatial and statistical properties of sample grades and block grades* – most observations or measurements of grade are made on samples, but estimates are usually defined on regular blocks. Any given block may comprise hundreds to thousands of samples and consequently, the spatial and statistical properties of samples and blocks can differ significantly. Ore is an economic definition based on mineable units and a sample is not a mineable unit. The direct use of sample grades to determine the spatial distribution of ore can lead to serious errors in the estimation of Mineral Resources.

A variety of Mineral Resource modelling approaches based on well documented and reliable geostatistical methods is currently available to allow robust estimation of Mineral Resources in most situations. In a broad sense, mineral deposits in which sample grades exhibit a low CV (< 1.0) and which will be mined at a relatively low cut-off, present the lowest risk profile for Mineral Resource estimation and ore definition. For such deposits, the ordinary kriging method would normally provide reliable Mineral Resource estimates.

With increasing cut-off grade and increasing CV, which are characteristics of more selective mining operations, the risks associated with Mineral Resource estimation and ore definition increase and estimation methods that allow more robust estimates in the presence of extreme grades and small block selection are more appropriate. Recoverable Mineral Resource estimation with non-linear methods, such as multiple indicator kriging and uniform conditioning, can provide better estimates than ordinary kriging in these situations.

Conditional simulation methods are also finding a place in Mineral Resource modelling as an alternative to the non-linear kriging methods in a range of situations, eg ore definition in grade control in both open pit and underground mines, and for controlling the variation in impurities in stockpiles of coal and iron ore.

The implementation of Mineral Resource estimation methods requires consideration of a range of important issues, such as data clustering, block size, data search strategy, geological domains and Mineral Resource classification. A good rule of thumb in resource modelling is to begin with a simple set of assumptions and parameters and justify added complexity and parameterisation by identifying associated beneficial effects in the model. If no significant beneficial effect can be identified, the additional complexity in the modelling should be removed. The tendency to begin by building complex resource models involving a range of block sizes with many complex geological domains and a large number of search criteria should be avoided.

6.1.4 Overview of mineral project valuation techniques

BACKGROUND

At the outset, it is critically important to appreciate that all valuations are time and circumstance specific so the chosen/nominated *Valuation Date* is critical. Also, all mineral property valuations are *subjective*, to various degrees, so their validity depends on the capability (qualifications and experience) and reputation of the valuer¹, who chooses both the appropriate method(s) and the quality/quantum and inherent riskiness of the assumptions and material parameters/input variables to be used. Hence, the value may change rapidly (positively or negatively) with additional exploration or changes in the relevant commodity market or the statutory, legal or socio-political framework.

Within the Australian minerals industry, the pre-eminent professional bodies are The Australasian Institute of Mining and Metallurgy (AusIMM) and the Australian Institute of Geoscientists (AIG). The origins of the Code and Guidelines for Assessment and Valuation of Mineral Assets and Mineral Securities for Independent Expert Reports (VALMIN Code) commenced in 1991 and the initial edition was published by these bodies in 1995, after extensive consultation with stakeholders. It was adopted by AusIMM on 17 February 1995 and applied to all relevant reports required under the Corporations Law 2001 from 1 July 1995. It was amended on 22 November 1997 and applied to all relevant Reports required under the Corporations Law 2001 issued on or after 1 April 1998. The 2005 Code (dated 20 April and approved by The AusIMM Board on 29 April 2005) replaced the 1998 Code, but the essential content and thrust remained the same (VALMIN Code, 2005).

The VALMIN Code is binding upon members of AusIMM and AIG when involved in the preparation of public '*Independent Expert Reports*' (IER) that are required under the *Corporations Act 2001*, or by the Listing Rules of the Australian Stock Exchange (ASX) or of other recognised stock exchanges. Clause 12 also made it clear that it should be followed for the technical assessments and valuations involved in most other valuation situations, particularly 'reports and expert witness statements provided for the purposes of litigation' (VALMIN Code, Clause 12[m]). It is endorsed and/or supported by ASX, the Australian Securities and Investments Commission (ASIC), the Mineral Industry Consultants Association (The Consultants Society of AusIMM), the Minerals Council of Australia and the Securities Institute of Australia as indicative of industry best practice.

Often a *Technical Value* is derived initially, to which a premium/discount is applied to reflect the positive/negative economic environment/share market, strategic or other considerations at the time of valuation, before estimating a *fair market value*. This intrinsic value (or technical value) of a mineral tenement depends upon the availability/extent of

1. 'Valuer' is 'Valuator' in Canada and 'Appraiser' in the United States.

reliable technical information on the project/tenement (mineral property) being valued and the due diligence and technical assessment skills of the valuer. Fair market value should be selected as the most likely figure from within a range, after taking account of risk and the possible variation in such things as ore grade, metallurgical recovery, capital and operating costs, commodity prices, exchange rates and the like and is defined in the VALMIN Code (2005) as follows:

It is the amount of money (or the cash equivalent of some other consideration) determined by the Expert in accordance with the provisions of the VALMIN Code for which the Mineral or Petroleum Asset or Security should change hands on the Valuation Date in an open and unrestricted market between a willing buyer and a willing seller in an 'arm's length' transaction, with each party acting knowledgeably, prudently and without compulsion (Definition 43).

IMPACT OF PROJECT DEVELOPMENT STATUS

The available information reflects the stage of development of the mineral property. It will range from those at the exploration stage (conceptual grassroots/greenfield and brownfield exploration prospects and those advanced exploration projects), through those in the predevelopment and development stage, to those finally operating as mines. The author first wrote about the difficulties in mineral property valuation (when tenements were at the early stage of development) in Lawrence (1989), then in Lawrence (1993 and 1994).

Grassroots exploration areas

These valuations range from areas for which there are only a geological concept or model and a granted tenement (or an application whose tenure is soon to be secured), through to ones for which conceptual targets have been generated and an exploration program has been designed and initiated. Remote sensing techniques (like airborne geophysics, Landsat satellite imagery and photogeology) may have been used to identify areas of interest for ground follow-up. Usually there will have been some on-site reconnaissance by geological and geochemical means (involving rock chip, soil and trench/pit sampling) and use of ground geophysical methods appropriate for the commodity sought, together with some scout drilling. Initial Exploration Results may provide evidence that a mineral occurrence exists, but its size, quality and value will be as yet unknown. Any encouraging Exploration Results obtained may suggest that the area is prospective, but no Mineral Resources have been delineated (ie nothing has been found that would qualify even as an Inferred Mineral Resource). Included here are those tenements for which there are prospecting results (ie low budget and small-scale exploration, which uses non-surface disturbance methods and which is mainly undertaken by individuals and syndicates, rather than companies).

Advanced exploration prospects

These are properties where considerable exploration has been undertaken and specific targets have been identified that warrant further detailed evaluation, usually by more closely-spaced systematic drill testing, trenching or some other form of detailed geological sampling. Thus, a mineral occurrence will have been discovered on them. Drilling and sampling will have delineated its dimensions (volume/tonnage) and geometry (orientation). A Mineral Resource estimate usually has not been able to be made as yet, but sufficient work will have been undertaken on at least one prospect to provide both a good understanding of the type of mineralisation present and encouragement that further work is likely to elevate

one or more of the prospects from Exploration Results into the Mineral Resource category. Some preliminary environmental, metallurgical, geotechnical and engineering data may have been obtained and some economic parameters generated, so that at the end of this stage it can be decided whether or not to complete a formal scoping study, which triggers a change of development status.

Predevelopment projects

These projects have enough data on them to confirm that the discovered mineral occurrence is now a mineral deposit. There exists sufficient preliminary estimates of its grade distribution and confidence in the geometry of the deposit for Mineral Resources (usually initially only Inferred Mineral Resources) to be identified but the extent is still incompletely known so that a decision to proceed with development cannot yet be made. Properties at the early assessment stage, properties for which a decision has been made not to proceed with development, properties on care and maintenance and properties held on retention titles are included in this category if Mineral Resources have been identified, even if no further valuation, technical assessment, Resource delineation or advanced exploration is being undertaken. The drilling spacing will have closed up and sampling will have established considerable Indicated and Measured Mineral Resources, but no Ore Reserves of any consequence. Investigations will focus less on geology and tonnage/grade and more on geotechnical, metallurgical and environmental data collection and study. Applications for the necessary governmental approvals and permits have been submitted. A prefeasibility study is undertaken in this stage to clarify the project's optimum production capacity and define development parameters and options for mining, treatment and transport. Preliminary estimates are made for the capital and operating costs and likely revenue. It involves Resource audits; metallurgical testing for process and mill design alternatives; mine planning and design optimisation studies; marketing reviews; and preliminary transport and sales contract negotiations. Whether or not it is an economically mineable deposit still depends on the delineation of adequate Reserves and obtaining favourable results from the feasibility study. This category extends until a decision to go ahead with the project has been taken, based upon the results of the feasibility study.

Development projects

Development projects are mineral properties for which a decision (based upon a feasibility study) has been made to proceed with construction and/or production, but which are not yet commissioned or are not yet operating/producing at design levels. Only when the feasibility study has been completed, can a decision to develop be taken, since there will be now adequate Ore Reserves (ie Mineral Resources that are technically feasible and economically viable to mine) for a realistic mine life. In some cases (eg alluvial gold/tin/diamond or coal projects), project owners may commence mining before Proven Ore Reserves are delineated (ie the spatial uncertainty may still justify only Indicated Mineral Resources and/or Probable Ore Reserves). Mineral Resource/Ore Reserves work continues, but it is of lesser importance as the focus has been on choosing options to exploit the deposit for maximum profitability (ie firming up of engineering design and construction criteria, the environmental management plan, and on optimising further components of the feasibility studies). Financial arrangements are being fine-tuned; sales contracts completed; the mine-mill-infrastructure construction tender process begins; as well as the negotiation of labour agreements and finalisation of all necessary governmental approvals and permits/licences.

Operating mines

In these circumstances, the mine-mill complex and necessary infrastructure have been constructed and commissioned, and all required government approvals and permits/licences are in place. Hence, the major risk components, in both socio-political (including environmental) and cash flow timing terms, have been removed (or quantified and risk management procedures implemented). This category also includes expanding operations and reopened 'mothballed' mines. The mine is now in production, shipping product to fulfil its sales contracts or market demand. There is continuing exploration to upgrade Mineral Resources to Ore Reserves depleted by mining and to locate additional mineralisation to replace Mineral Resources.

VALUATION METHODOLOGY CHOICE BASED UPON DEVELOPMENT STATUS

The amount of reliable data available usually determines the appropriateness of the valuation methodology to be used (see Table 6.1.1 for the specific stages of development of knowledge about the project).

TABLE 6.1.1
Stages of development of project knowledge^a.

Technical review approach	Exploration properties	Development properties	Production properties	Dormant properties		Defunct properties
				Economically viable	Not viable	
Cash flow	Not generally used	Widely used	Widely used	Widely used	Not generally used	Not generally used
Sales comparative	Widely used	Less widely used	Quite widely used	Quite widely used	Widely used	Widely used
Cost	Quite widely used	Not generally used	Not generally used		Less widely used	Quite widely used

- a. Source: Figure 1 from The South African Code for the Reporting of Mineral Asset Valuation (The SAMVAL Code), prepared by The South African Mineral Asset Valuation (SAMVAL) Working Group. Available from: <http://www.samval.co.za>
Reproduced with the kind permission of The Southern African Institute of Mining and Metallurgy.

The overall process is to move from conceptual geological modelling to a scoping study, to a prefeasibility study, to a feasibility study and then final design/construct/commissioning contracts before it moves to production as an operating mine, see Figure 6.1.14. Each has an increasing level of confidence and certainty to its conclusions, due to an increasing level of accuracy and precision in the inputs.

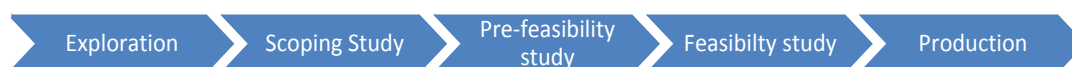


FIG 6.1.14 - Stages of project study.

Ignoring any legal impediments, the basic principle is that a newly discovered mineral deposit is sequentially subjected over time to increasingly more detailed and rigorous examinations of whether it should be developed and ultimately mined. Essentially, this is done by taking the geological Exploration Results and determining (with confidence)

the amount of saleable quality mineralisation present (Resources/Reserves), which it is technically feasible to exploit and economically sound to do so, by examining in increasing detail *all* the available mining, treatment, transport and marketing options that could be used in the ultimate financial analysis. Also involved, for example, are increasingly more detailed associated geotechnical, hydrological, environmental, archaeological, native title and social studies.

The ultimate objective is to produce a document that does (or does not) support the internal or external allocation of funds to develop the deposit into a mine (feasibility study). To do so it must contain all relevant and reliable information, which investors and their professional advisers would reasonably require and would reasonably expect to find, for the purpose of making a reasoned and balanced judgement on the subject of the feasibility study.

To put the project study issue in better context, the three main types of studies of mineral projects that are applicable to their stage of development and the extent and availability of geoscientific and related financial information on costs and revenue predictions, are described below.

- *Scoping study* – asking what the mineral project *could* be; and whether it is sensible to continue to explore it. It is a preliminary initial review and expected to have study inputs accurate to only ± 40 per cent to 50 per cent.
- *Prefeasibility study* – asking what the mineral project *should* be; and whether the optimum way forward (project configuration and parameters) has been identified by examining and reviewing *all* of the available options/alternatives. It is expected to have study inputs accurate to ± 20 per cent to 25 per cent.
- *Feasibility study* – what the mineral project *will* be; what the likely risks and rewards involved with the chosen project configuration/parameters are; and the investment case is unlikely to vary significantly because of the thoroughness and due diligence exercised to select the scenario adopted. It is a holistic techno-economic and socio-political analysis that must have sought to identify and propose management of all the possible ‘project killer’ risks and provide a reliable estimate of project value upon which an investment decision can be made. Often the term ‘bankable’ is added to emphasise this primary purpose. It is expected to have study inputs accurate to ± 10 per cent to 15 per cent.

It is also necessary during the process to identify the risks involved, quantify them and develop a risk management/mitigation regime to address their likely impact on the ultimate profitability of the project. This ranking enables better investment decisions to be taken.

The content of material agreements and the actual equitable interests held (or to be earned) are also relevant in allocating the estimated value amongst the participants; as is the security of tenure/title and legal standing / type of the tenement involved (eg exploration licence / mining lease, etc).

Exploration tenements have value based mainly upon their demonstrable prospectivity and success of previous exploration effort, ranging from remote sensing to actual drilling of deposits to test their economic interest. This work aims to demonstrate the existence of mineralisation capable of being mined, processed and sold at the required level of profit. The value of more developed projects resides in the quantity/quality of the deposit that will be exploited to yield a profit over time. Integral to this process, then, is the careful transition from Exploration Results, through Mineral Resources (Inferred to Indicated to Measured), to Ore Reserves (Probable and Proven), see Figure 6.1.15. This transition occurs as confidence grows in the reasonableness of the interpreted geometry and bulk density of the deposit (tonnage) and the reliability (accuracy/precision) and its estimated grade.

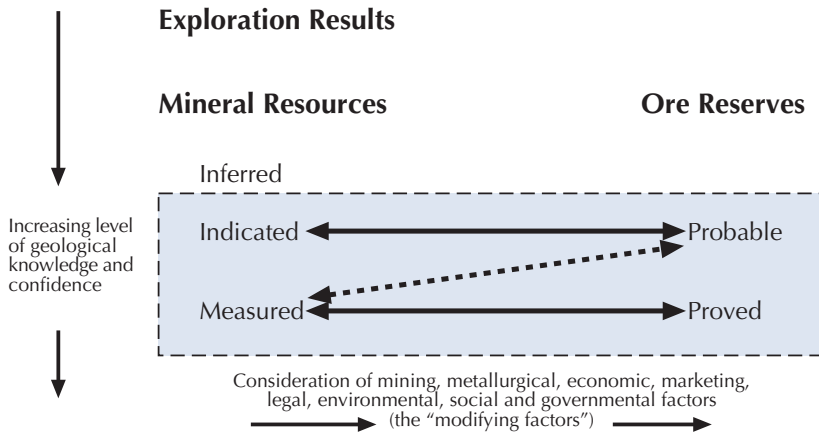


FIG 6.1.15 - General relationship between Exploration Results, Mineral Resources and Ore Reserves (source: JORC Code, 2004, p 6).

There are numerous technical studies involved in this progression to the final identification of the quantity of material that it is technically feasible to mine and treat, transport and ultimately sell (Ore Reserves); and that it is legal and economically viable to do so at the time. The modifying factors applying to the Mineral Resource estimate thus include mining, metallurgical, economic and marketing considerations; but also legal, environmental, social and governmental factors (see JORC Code (2004) from which Figure 6.1.15 is taken).

The core assumption of the VALMIN Code (2005) is that mineral industry professionals (eg geologists, mining and metallurgical engineers as well as environmental specialists) should provide the technical assessment input and take responsibility for their contribution to the resultant value.

The broad aim in a valuation is to achieve TRANSPARENCY in the MATERIAL information to be presented by COMPETENT and INDEPENDENT valuation practitioners so that it can satisfy an overall REASONABLENESS test. The valuers must belong to appropriate national professional institutes that have enforceable ethics codes and attest to the education/qualifications/experience (competence) and repute of the valuer.

The valuation must not be false and misleading, ie essentially rational and realistic valuation methods appropriate to the commodity and state of development of the project are used so that the result is reasonable and reliable (accurate and precise) as at the Valuation Date.

The VALMIN Code (2005) has been a model for the development of analogue valuation Codes in other mining jurisdictions (albeit with some local adjustments to accommodate their own circumstances), eg Canada (CIMVAL Code) and South Africa (SAMVAL Code).

In addition, where directors choose to provide an *IER* in the target statement in order to assist shareholders to make an informed decision about a takeover offer, the views expressed by ASIC in their Regulatory Guide 111 Content of Expert Reports (RG 111) is important guidance on how the offer should be evaluated and presented to shareholders. It provides particular guidance on how to determine whether or not a proposed transaction is 'fair and reasonable'. A takeover offer is considered 'fair' if the value of the offer price or consideration is equal to or greater than the value of the securities that are the subject of the offer; a takeover offer is considered 'reasonable' if it is fair or, where the offer is 'not fair', it may still be 'reasonable' if the expert believes that there are sufficient reasons for

security holders to accept the offer in the absence of any higher bid before the close of the offer. RG 111 also states that the IER should focus on the issues facing the security holders for whom the report is being prepared; and the substance of the transaction rather than the legal mechanism used to achieve it.

In any event, both the ASX and ASIC (investment regulatory bodies) rely on the VALMIN Code as a guide to best practice in mineral valuation matters.

The general matters to be addressed in a valuation are set out in the following extract from the VALMIN Code (2005, p 11):

CONTENT OF A REPORT

50. A Report is likely to be used by readers having different interests and depths of technical knowledge. For the sake of clarity, but recognising that the use of technical language is sometimes essential (in which case a glossary of terms may be helpful), the Report should be written in plain English and *must* contain all information which the Commissioning Entity and others likely to rely on the Report, including investors and their professional advisers, would reasonably require, and reasonably expect to find in the Report, for the purpose of making an informed decision about the subject of the Report. For example:
 - (a) information regarding the sources of data used;
 - (b) a description of the relevant Mineral or Petroleum Assets, including their location, plant, equipment, infrastructure and ownership;
 - (c) an account of the Material history of the Mineral or Petroleum Assets;
 - (d) sufficient information to allow experienced investment analysts to understand how the Technical Assessment and/or Valuation was prepared, including details (summarised if appropriate) of any financial model used and of sensitivities to variation;
 - (e) sufficient information about the valuation method(s) used so that another Expert can understand the procedures used and replicate the Valuation;
 - (f) a review of any other matters that are Material to the Report;
 - (g) a balanced, objective and concise statement of the Expert's review and conclusions so that an informed layman can have a clear understanding of the Mineral or Petroleum Assets or Securities concerned, their Value (if applicable) and of the attendant Risks;
 - (h) a concise summary setting out the key data and important assumptions made and the conclusions drawn by the Expert and/or Specialists, qualified if necessary according to the insufficient or inadequate information provisions of Clause 54.
51. Detailed technical information and data should be included in the Report if their understanding is important to the Technical Assessment or Valuation. Explanations of unusual or new technical processes and activities that may be Material to the understanding of the Technical Assessment or Valuation should be included, where commercial confidentiality considerations allow. The use is encouraged of tables, maps, graphical presentations and a glossary of terms and acronyms.

52. Experts and Specialists *must* not rely uncritically on the data and other information provided, by the Commissioning Entity or obtained otherwise. They *must* undertake suitable checks, enquiries, analyses and verification procedures to establish reasonable grounds for establishing the soundness of the contents and conclusions of the Report.
53. The data used *must not* have been rendered invalid due to the passage of time and consequent changes in such items as capital and operating cost structures, exploration techniques, geological interpretation and mining and metallurgical technologies.
54. Where it is impossible or impracticable to obtain sufficiently accurate or reliable data or information as the basis for a Technical Assessment or a Valuation, this *must* be stated in the Report by the Expert or Specialist. In these circumstances, the Expert or Specialist would be under no obligation to express an opinion and/or provide a Valuation.
55. *The Expert or Specialists should ensure that summaries of existing reports that have been prepared by others are accurate and that any quotations from them are in the form and context intended by the original authors.*
56. *A Report must not include a report or quotation that is the work of another person without his or her written (and not subsequently withdrawn) consent, unless such consent is either:*
 - (a) *not required by law or*
 - (b) *the Report is within the public domain and not subject to copyright or if*
 - (c) *the circumstances are such that, in the reasonable opinion of the Expert or Specialist, it would be impossible, impracticable or abnormally expensive to obtain such a consent.*

BACKGROUND ON RELEVANCE OF JORC (2004) AND VALMIN (2005) CODES

The need for using JORC Code (2004) terminology in mineral property assessments when reporting mineralisation confidence categories and use of those valuation terms used in the VALMIN Code (2005) is so that minerals industry professionals will have a common terminology and know what is being disclosed, otherwise there is a potential to mislead others, even if inadvertently. Claimed JORC- and VALMIN-compliance is a quality assurance qualifier, so it must be validly asserted.

JORC Code

It has already been noted that the identification of an appropriate quantity and quality of Mineral Resources and/or Ore Reserves is critical to the assessment of a project. Whilst Resources have a fair market value, it is clear that Ore Reserves must be delineated if the project is not internally funded and it requires project finance or loan funds from a credit provider. In the author's experience, banks will lend only on the basis of Proven and Probable Ore Reserves, with a requirement for a substantial portion of the Ore Reserves to fall into the Proven category. This is because history indicates that more projects fail because the Ore Reserve prediction/estimate does not eventuate, than for any other reason. Hence, this highlights the general importance of identifying Ore Reserves (rather than Mineral Resources) and obtaining the highest confidence JORC Code categories as possible for a valuation.

The following extract (Clause 23, pages 8 to 9) from the JORC Code (2004) is seminal to any initial assessment of a project. It identifies the inherent problem in not having confidence in the geometry of the deposit (ie the risk that the assumed quantity/quality may not be there – this risk decreases as one moves from Inferred to Measured Resources).

23. The choice of the appropriate category of Mineral Resource depends upon the *quantity, distribution and quality of data available and the level of confidence that attaches to those data*. The appropriate Mineral Resource category must be *determined by a Competent Person* or Persons.

Mineral Resource classification is a matter for skilled judgement and Competent Persons should *take into account those items in Table 1 which relate to confidence* in Mineral Resource estimation.

In deciding between *Measured* Mineral Resources *and Indicated* Mineral Resources, Competent Persons may find it useful to consider, in addition to the phrases in the two definitions relating to geological and grade continuity in Clauses 21 and 22, the phrase in the guideline to the definition for Measured Mineral Resources: ‘.... *any variation* from the estimate would be *unlikely to significantly affect potential economic viability*’.

In deciding between *Indicated* Mineral Resources *and Inferred* Mineral Resources, Competent Persons may wish to take into account, in addition to the phrases in the two definitions in Clauses 20 and 21 relating to geological and grade continuity, the guideline to the definition for Indicated Mineral Resources: ‘Confidence in the estimate is sufficient to allow the application of technical and economic parameters and to enable an evaluation of economic viability’, which contrasts with the guideline to the definition for Inferred Mineral Resources: ‘*Confidence in the estimate of Inferred* Mineral Resources is usually *not sufficient to allow* the results of the application of technical and economic parameters to be used for *detailed planning*.’ And ‘*Caution should be exercised if this category is considered in technical and economic studies* [author’s emphasis].

Whilst quantification is up to the Competent Person, the basis for the selection and use of the various Mineral Resource confidence category terms (Inferred, Indicated and Measured Resources) needs to be discussed and justified much more in project assessment reports. Often the use of the terms alone might not properly convey the real level of confidence (accuracy and precision) in the Mineral Resource/Ore Reserve category quoted. They are an estimation not a calculation and the simple use of JORC Code terms alone does not imply that the Mineral Resource or Ore Reserve estimates will turn out to be what was thought to exist in the ground.

The JORC Code’s focus, then, is on the provision of accurate, material disclosure, to aid the making of proper investment decisions. A reader is to be:

... *provided with sufficient information, the presentation of which is clear and unambiguous, to understand the report and is not misled* (JORC Code, 2004, p 2).

It goes on to say:

... *there may be occasions when doubt exists as to the appropriate form of disclosure. On such occasions, users of the Code and those compiling reports to comply with the Code should be guided by its intent, which is to provide a minimum standard for Public Reporting, and to ensure that such reporting contains all information which investors and their*

professional advisers would reasonably require, and reasonably expect to find in the report, for the purpose of making of a reasoned and balanced judgement regarding the Exploration Results, Mineral Resources or Ore Reserves being reported (JORC Code, 2004, p 3, author's emphasis).

The point is that the quantities/qualities claimed to exist in the project must be JORC Code compliant because they should be based upon the best objective data available and not rely upon unsupported assumptions. A report should contain all the required data shown in Table 1 in the JORC Code (2004), because it is a checklist of the numerous items required to be verified when deciding to assign a Resource confidence category (see page 14, JORC Code).

The 'modifying factors' to be applied to convert Resources into Reserves (which include consideration of mining, metallurgical, marketing, economic, legal, environmental, social and government factors) also must be outlined and justified. They are supposed to have been determined from an adequate feasibility study. Note, too, that less confidently geometrically established Indicated Resources normally become only Probable Reserves and more confidently geometrically established Measured Resources are required to go to Proven Reserves. Clearly this type of detailed data has to be provided to minimise the risk that the claims about the project do not eventuate because there is not enough ore to mine/process and sell.

VALMIN Code

The VALMIN Code is a guide to project technical assessment and valuation best practice to which minerals industry professionals adhere (eg members of AusIMM and AIG). It is endorsed and/or supported by the ASX², ASIC, Mineral Industry Consultants Association (MICA), the Minerals Council of Australia (MCA) and the Securities Institute of Australia, as indicative of industry best practice. The national securities and investment regulator ASIC particularly expressed its support for the VALMIN Code as follows:

The Australian Securities and Investment Commission (ASIC) refers to the VALMIN Code when reviewing mining and exploration prospectuses and takeover documents. ASIC regards the Code as indicative of best practice, and expects that when specialist mining terms used in the Code are contained in such documents that they will have the same meaning as in the Code.

Although the VALMIN Code's primary purpose is to provide guidance on the preparation of public investment reports (IERs under the Corporations Law), its Clause 12 makes it clear that it should be followed for the technical assessments and valuations involved in most other valuation situations, particularly 'reports and expert witness statements provided for the purposes of litigation' (VALMIN Code, Clause 12[m]).

It also requires that those technically assessing mineral projects do not simply uncritically accept everything provided to them by the interested parties, as summarised in the following extract.

*Experts and Specialists **must** not rely uncritically on the data and other information provided, either by the Commissioning Entity or obtained otherwise. They **must** undertake suitable checks, enquiries, analyses and verification procedures to establish reasonable grounds for establishing the soundness of the contents and conclusions of the Report (VALMIN Code, 2005, Clause 52, page 11).*

2. At the time of writing, the Australian Stock Exchange has not mandated the use of the VALMIN Code within its Listing Rules.

Hence, the need to pay attention to detail to ensure presentation of robust data that has been verified or obtained from reliable sources to satisfy the essential requirement of due diligence.

Finally, it is a necessary part of the usual due diligence required of mineral tenement assessors for assessors to make themselves *independently* aware of those factors that are material to the valuation of the exploration tenements. They include material contracts and agreement, the actual area involved, geological location, difficulty of access, rates, rents and minimum exploration expenditure required by the government to be spent within the time of tenure. It is common practice to sight copies of the actual departmental grant/renewal documentation in order to satisfy this due diligence obligation, because errors can occur if primary source data is not seen.

The essential and defining character of technical assessment and/or Valuation Reports is that they must provide readers with all the relevant information that the intended recipient investors and their professional advisers would reasonably require, and reasonably expect to find in it, for the purpose of making a reasoned and balanced investment judgement on the technical feasibility and financial viability of the project. This explicitly requires that the relevant information must be complete, accurate and true so that it can be relied upon by the reader.

Codes and reporting

The key requirements for mineral industry reporting are that it satisfies three core criteria:

1. materiality (ie it supplies all such information that enables the making of a properly informed investment decision)
2. transparency (ie it presents comprehensive, thorough or sufficient information, clearly, and unambiguously, so that it is easily understood and does not mislead)
3. competency (ie it is prepared by an appropriately qualified and experience professional, so that its conclusions are reliable).

These desirable principles are echoed throughout the ASX/ASIC reporting requirements; as well as specifically in the JORC Code (2004) and VALMIN Code (2005), which provide best practice guidance on the content of various mineral industry reporting documents. All of these requirements sit within an overall envelope of reasonableness.

A valuation must contain all relevant and reliable information that investors and their professional advisers would reasonably require and would reasonably expect to find there, for the purpose of making a reasoned and balanced judgement and investment decision, the subject of the valuation.

See below extracts from the JORC Code (2004) and the VALMIN Code (2005), to illustrate and provide the background criteria in support of this opinion:

Materiality requires that a Public Report contains all the relevant information which investors and their professional advisers would reasonably require, and reasonably expect to find in the report, for the purpose of making a reasoned and balanced judgement regarding the Exploration Results, Mineral Resources or Ore Reserves being reported.

Transparency requires that the reader of a Public Report is provided with sufficient information, the presentation of which is clear and unambiguous, to understand the report and is not misled.

Competence requires that the Public Report be based on work that is the responsibility of suitably qualified and experienced persons who are subject to an enforceable professional code of ethics.

PURPOSE OF THE CODE

1. The purpose of the VALMIN Code is to provide a set of fundamental principles and supporting recommendations regarding good professional practice to assist those involved in the preparation of Independent Expert Reports^{D14} that are public and required for the assessment and/or valuation of Mineral^{D20} and Petroleum^{D26} Assets and Securities^{D31} so that the resulting Reports will be reliable, thorough, understandable and include all the Material^{D16} information required by investors and their advisers when making investment decisions.

Other purposes for which the VALMIN Code, in whole or in part, should be followed are Technical Assessments and Valuations involved with:

- (h) the justification for raising debt or equity finance from an outside party, when not excluded by the provisions of Clause 8;
- (i) facilitating negotiations between partners;
- (j) the assessment of Government charges and taxes;
- (k) estate settlements;
- (l) internal corporate reports for directors;
- (m) reports and expert witness statements provided for the purposes of litigation;
- (n) stamp duty assessments on the transfer of Tenements;
- (o) stamp duty valuations;
- (p) assistance to receivers or managers engaged in the disposal of assets;
- (q) reports for receivers and administrators;
- (r) valuations for tax assessments;
- (s) accounting and financial reporting.

Clause 30 of the VALMIN Code (2005) provides also for a '*Reasonableness Test*' to be applied to valuations and technical assessment reports (see below):

30. A Valuation or Technical Assessment should not be provided unless a suitably objective Reasonableness Test (D29) has been applied, based on facts and not on unsubstantiated opinion.

D29 Reasonableness Test means an impartial assessment to determine if the overall valuation approach used is rational, realistic and logical in its treatment of the inputs to a Valuation to the extent that, having the same data and information about an Asset, another Expert or Specialist would make a similar Technical Assessment of and/or value it at approximately the same level. Such a test will serve to identify Technical Assessments or Valuations that may be out of line with industry standards and norms.

VALUATION METHODOLOGIES

Introduction – semantics and communication

It is critical to this topic that various key terms and concepts involved are clearly understood. Thus, there is a glossary given in Appendix 2 at the end of this volume, where various terms and concepts are defined, to reduce the need for semantic arguments and to improve future communications. Also, Lawrence (1992) and Lawrence and Sorentino (1994) provide a useful bibliography of mineral valuation papers at those times; as does the annotated valuation paper reviews in Lawrence (2000d).

There is no doubt that various jurisdictions have slightly different meanings for the various concepts and valuation methods available, but the glossary attempts to set out the various terms used in this paper to clarify the author's position. This will hopefully allow the reader to concentrate on the concepts presented rather than focus on definitional issues (important as they are ultimately). It also has the potential to create an internationally accepted nomenclature that will aid understanding of 'mineral asset' and 'valuation' at the international level.

The first problem is to identify which of the four general property types are being valued: 'real property'; 'personal property'; businesses; or financial interests. Mineral assets do not easily fit the International Valuation Standards Committee (IVSC) categorisation, since one might use Guidance Note (GN) 1 (for real property) or GN6 (for businesses), depending on if one is valuing exploration prospects, projects or mines (IVSC, 2000). In fact, the IVSC has created a subcommittee to examine the creation of a specific GN for the 'Minerals (Extractive) Industry'.

At first glance, the conventional tripartite classification of valuation approaches (into those that are *market-based*, *income-based* and *cost-based*) is a reasonable and useful one. However, the allocation of valuation methods into these convenient categories is seen as rather arbitrary upon closer analysis. These classification attempts have also caused some confusion over the meaning of the widely used term 'Market Value'. Nevertheless, it is best valuation practice for the 'Valuer'; also for 'Expert' and 'Specialist' to use as many of the three basic valuation approaches as possible (and as many their component methods as reasonable in the particular circumstances), given the development status and consequential quantity and quality of the data available.

However, the selection of the specific valuation method(s) to be used should always be left up to the discretion of the valuer. The use of specific methods must satisfy the basic considerations of logic and reasonableness, having regard to the development status of the mineral asset and the purpose of the valuation.

Because of the diversity of situations in which a valuation could be required, no simple standard formulas can be used in Mineral Asset Valuations. In particular, the market is not as efficient nor as open and unrestricted as many assume. The competence and judgement of the valuer is the critical factor, since *all valuations (especially market-based ones) are time and circumstance specific and there is no best method*.

As a result of the introduction of the VALMIN Code (2005), initially in 1995 and its revision in 1998, technical assessment reports and valuations of mineral assets and securities prepared in conformity with it are now much more comprehensible and reliable than before. This is mainly because of the Code's key requirements of 'Transparency' and 'Materiality', 'Competence' and 'Independence' when required, within an overall context of 'Reasonableness'. The main focus has been on more complete and non-misleading disclosure (ie providing investors with all the necessary (relevant and material) information that they reasonably require so that they can make an informed decision). For a fuller discussion of the basis and usefulness of the VALMIN Code see Lawrence (1995; 1998a, 1998b and 1998c; 1999a, 1999b and 1999c; 2000b, 2000c and 2000d); and for an account of the VALMIN Code's history see Lawrence (2000e).

Equitable interest in the mineral asset being valued

The simplest case would be where a party already appears to own 100 per cent interest in a mineral asset. However, even then, one should be cognisant of the impact of various

government royalties (say four per cent) or of third-party interests if the discounted cash flow (DCF)/net present value (NPV) method is used. Their effect is that less than 100 per cent of the estimated value should be attributed to the owner, since such royalties represent some loss of equity in a project.

Related to this issue is the possible existence of other non-governmental royalty owners or those with free carried (or limited contribution) interests, who may be hidden away in the material agreements and tenement transfer dealing documents. It is critical that a thorough due diligence is performed in this area, since it affects the allocation of the estimated total value amongst the parties.

In addition, where a tenement is being valued subject to an option-to-purchase agreement (unless that agreement is irrevocable and funds are realistically available; or it will be exercised and full payment will be effected imminently), the tenement generally has only a nominal or no value to the option holder, in a pretransactional context. However, it could have a value to the option holder in a post-transactional sense, but it must be smaller than if the interest had been already acquired. Otherwise, one has the illogical situation where the owner of an actual interest in a tenement has the same value as that assigned by the valuer to one who may purchase or will earn that right in the future with its attendant risk. In this latter case, some discount must be applied to the normal value to account for the probability that the deal might not be finalised, no matter how small that risk might be estimated to be by the valuer. It is not a debate about quantum, but about logic.

In the author's opinion, the values of mineral assets subject to Aboriginal land rights (native title) claims should also be discounted by a risk factor (say 20 per cent, depending upon the circumstances) to distinguish those that are affected by this constraint from those that are not. This is because of the real increased delay in any project's development on them; and the significant associated costs involved, particularly the likely high additional legal/administrative costs and payments/royalties or concessions involved.

Similarly, the author believes that tenements under application (especially exploration tenements) must also be discounted to some degree. This takes account of the possibility that they may not be granted in a timely way (or even granted at all); and the fact that no one, as yet at the valuation date, holds any real equitable interest in the right to mine under known conditions. If there is no discount, then there is the absurdity that there is no difference in the value of a mining asset, whether or not one holds a granted tenement with known conditions and enforceable financial commitments over the asset.

What value is being estimated?

Valuers in Australasia are primarily asked to determine the 'fair market value' (or 'market value') of a mineral asset at a certain 'valuation date'. Readers must understand that this term is not simply referring to the value determined by use of the market approach. It is a more generic term for current worth of an asset in the marketplace derived by any valid methodology consistent with the principles set out below. See Lawrence (2002c) for a more detailed review of the nature of 'market value.'

Also, 'value' does not always equal 'price'. The latter represents the historical reality of what was paid for an asset, not the future estimate of what is likely to be paid for it (after considering the financial motives, capabilities or special interests of the purchaser; and the state of the market at the time).

Then there is the issue of whether an asset is to be valued as a stand-alone item or within a corporate structure. Market approach methods that rely upon market transactions involving

market capitalisation data (or transactions for entities rather than projects) must take these factors into account by adjusting the transaction values used in order to obtain comparable data. Note that this section of the chapter does not specifically deal in detail with the more complex subject of valuation of company shares and securities and the use of financial multipliers (price/earnings or price/cash flows ratios, on various criteria).

Case law and precedent in mineral valuations

The main Australasian authority for fair market value principles is the High Court Appeal case *Spencer v Commonwealth of Australia* (1907-08) 5 CLR 418. This case dealt with the determination of fair and just compensation to be paid following the Federal Government's resumption (compulsory purchase)³ of land in 1905 for a fort at Fremantle, Western Australia. The Court said that the value was to be at the valuation date according only to the facts existing then and claimed that:

... all circumstances subsequently arising are to be ignored. Whether the land becomes more valuable or less valuable afterwards is immaterial (Spencer at 440).

It also made the important point that the value paid should be such that it:

... will place the dispossessed man in a position as nearly similar as possible to that he was in before (Spencer at 435)⁴.

Also, it was to be the unencumbered value.

The High Court pointed out that the value was:

... what it is worth to a man of ordinary prudence and foresight, not holding his land for merely speculative purposes, nor, on the other hand, anxious to sell for any compelling or private reason (Spencer at 437).

It stressed that the hypothetical seller, in the process of voluntary bargaining, must be:

... willing to sell as a business man would be to another such person, both of them alike uninfluenced by any consideration of sentiment or need (Spencer at 437).

Note that the general principle is that one seeks the 'Value-in-Exchange'⁵ (or value in the marketplace) not 'Value-in-Use' (or value to the owner). The latter term implies higher value to a specific purchaser for the asset's specific use in the purchaser's business (see below and glossary (Appendix 2) for a fuller discussion and definitions of the terms). Nevertheless, the High Court did allow consideration of the reasonable future use of the asset (Spencer at 436)⁶ by a hypothetical buyer, since it did not require that the willing purchaser be actually available on the Valuation Date to buy it (Spencer at 432). This is the 'Highest-and-Best-Use' concept.

The High Court went on to say (Spencer at 440-441) that the fair price of the land was that:

*... which a hypothetical prudent purchaser would entertain, if he desired to purchase it for the most advantageous purpose for which it was adapted.*⁷

3. Also termed a 'condemnation', 'eminent domain' or 'taking' in other jurisdictions.

4. This is a quotation by Barton J in 1908 taken from the prior Supreme Court of New Zealand case of *Russell v The Minister of Lands*, 17 NZLR 241 (at 253).

5. See *Peko Wallsend Operations v Commissioner of State Taxation (WA)* 89 ATC 4569 (at 4587) applying the principle first outlined in *Spencer v Commonwealth of Australia* (1907-08) 5 CLR 418.

6. Barton J believed that 'special advantages' of the land and 'all reasonably fair contingencies' should be taken into consideration.

7. This is the highest-and-best-use concept again.

It was to be sold:

... not by means of a forced sale, but by voluntary bargaining between the plaintiff and a purchaser, willing to trade, but neither of them so anxious to do so that he would overlook any ordinary business consideration.

It was to be supposed that both parties were:

... perfectly acquainted with the land, and cognisant of all circumstances which might affect its value, either advantageously or prejudicially.

These factors included its:

... situation, character, quality, proximity to conveniences or inconveniences, its surrounding features and the then present demand for land.

Finally, there was to be included consideration (by appropriate experts) of the likelihood:

... of a rise or fall for what reason soever in the amount which one would otherwise be willing to fix as the value of the property.

Unfortunately for mineral asset valuers, many legal precedents (here and overseas) have fixated on the comparable sale approach (that forms the basis of 'real estate' property transactions) as the only determiner of true value for supposedly similar assets, such as mines. This has been at the expense of better estimation methods in certain circumstances (eg DCF/NPV analysis) because the Courts then were convinced all these other methods were too subjective. Courts also seem to be generally unaware of the unique characteristics of mineral assets when compared with real estate properties. In addition, most are purchased because of what they *contain* (Mineral Resources of the commodity to be mined and sold), rather than for their *use* (the basis of real estate transactions). Unfortunately, this is why it is sometimes still argued in Courts that:

... where there are no anomalies affecting a market, the price at which property changes hands in the ordinary course of business and the market, is usually its true value.⁸

Fair versus market value

The matter of value is clouded somewhat because accountants have defined 'fair value' and 'market value' as separate terms. Although they can be the same numerically, in practice (perhaps this is the origin of the term 'fair market value' used in the securities/minerals industry and in the VALMIN Code) a distinction is maintained between them by the IVSC. This potential confusion is exacerbated by the Uniform Standards of Professional Appraisal Practice (USPAP), recommended for use in the United States. It, too, recognised the subtle differences between them.

In essence, fair value (IVSC definition) is the service value of an asset determined in conditions other than those prevailing in a normal market, by means other than by using market sales comparison data (eg by DCF/NPV method). Fair value is not the value realised from a forced sale or liquidation of the assets ('forced sale value').

Market value (IVSC definition), simply put, is the result of an objective calculation of specific identified ownership rights to a specific asset as at a given date. It is similar to the VALMIN Code's definition (based upon the *Spencer Case* and as described below), but it properly emphasises a need for adequate marketing time (but it unduly favours use of comparable market data in the author's opinion).

8. See Malcolm CJ in *Commissioner of State Taxation (WA) v Nischu Pty Ltd 91 ATC 4371 (at 4376)* who also listed a Federal Court case and a South Australian Supreme Court case in support of this view.

International value definitions

In Australasia, fair market value (VALMIN definition) is the estimated amount of money (or the cash equivalent of some other consideration) for which the mineral asset should change hands on the valuation date. It must be between a willing buyer and a willing seller in an arm's length transaction in which each party has acted knowledgeably, prudently and without compulsion.

In Canada, fair market value is:

... the highest price available in an open and unrestricted market between informed and prudent parties, acting at arm's length and under no compulsion to act, expressed in terms of money or money's worth (according to Lawrence, 2000b).

The US definition of market value (USPAP, 1998) is very much linked to the real estate concept. It is:

... the most probable price that a property should bring in a competitive and open market under all conditions requisite to a fair sale, the buyer and seller each acting prudently and knowledgeably, and assuming the price is not affected by undue stimulus. Implicit in this definition is the consummation of a sale at a specified date and the passing of title from seller to buyer under conditions whereby:

- *buyer and seller are typically motivated;*
- *both parties are well informed or well advised, and acting in what they consider are their best interests;*
- *a reasonable time is allowed for exposure in the open market;*
- *payment is made in terms of cash in United States dollars or in terms of financial arrangements comparable thereto; and*
- *the price represents the normal consideration for the property sold unaffected by special or creative financing or sales concessions granted by anyone associated with the sale.*

Unfortunately, many of the strict requirements specified above do not apply in the real world. For example, equal willingness to deal and equal negotiating power; existence of a total arm's length relationship; equality of knowledge about the asset; equal levels of prudence; openness and equilibrium of the market; and non-tangible components being involved.

Also, there are numerous circumstances in which a valuation is required, but for which the market value (in the strict sense) is not derived. For example, forced sales and liquidations; corporate reconstructions or mergers; taxation and rating purposes; settlement of legal and insurance claims; joint venture buy-outs; inheritance distributions; various accountancy uses, etc. This is probably why accountants have clung to the fair value concept to impart a more practical, market-based flavour to the values reported.

In fact, one could argue that even in those cases where it is supposedly provided, there is no guarantee that it is the real market value. Requiring the valuation to be 'independent' should provide some measure of guarantee, but even this is debateable in some hostile takeovers and litigation.

Valuation methodology fundamentals

The author is mindful of the limitations of mineral asset valuation methodology, admitting that many elements are undeniably subjective, but maintains that the values obtained are by no means guesswork. In any event, an honest, subjective experiential valuation is often

more realistic than a sophisticated one out of a computer. See Lawrence (1989, 1993 and 1994) and Thompson (2002) for an overview of the valuation methods available for valuing exploration properties. For specific commodity examples see Lawrence and Hancock (1992), which reviews alluvial gold valuation issues; and Lawrence (2007), which examines valuation methodology options for iron ore.

To achieve a persuasive result, there must be some demonstrably rational basis to the chosen valuation method, else it becomes nothing more than financial engineering of the 'What-number-did-you-have-in-mind?' school. Whether or not inappropriate methodology is used, too often one sees blatant abuse of logic in the choice of inputs or the way the chosen method is interpreted. See Lawrence and Dewar (1999) for details and examples.

The conventional tripartite classification of valuation approaches (into those that are *cost-based*, *market-based* and *income-based*) is a reasonable and useful one. It is best valuation practice for the valuer to use as many of these three basic valuation approaches as possible (and as many of their component methods as reasonable in the particular circumstances), given the development status and consequential quantity and quality of the data available.

Discounted cash flow (DCF) / net present value (NPV) method (income-based)

This method can be used for some predevelopment, but all developing projects and operating mines, because there exists sufficient, reliable information to make realistic calculations in an economic model worth attempting. Measured and Indicated Mineral Resources have been estimated (even Ore Reserves) and mining, processing, transport and commodity input data are known or can be reasonably assumed (from scoping, prefeasibility or feasibility studies) such that an estimate of value can be derived with a reasonable degree of confidence. Numerous papers exist discussing this method so only brief mention is made of it here, with the main focus being on valuation methodology applicable to the bulk of mineral properties where there is insufficient data available to enable its use. See Lawrence (2000a) for a critique of the misuse of the DCF/NPV modelling method.

The multiple of exploration expenditure (MEE) method (cost-based)

This can be used where useful previous and committed future exploration expenditure is known or can be reasonably estimated. This method is based on the experiential reality that a 'grassroots' exploration area commences with only a nominal value that reflects the cost of obtaining the legal right to explore and that its value increases proportionately with the obtaining of positive exploration results from increasing exploration expenditure; and the premise that a vendor requires reimbursement of the funds spent plus some premium related to the risks taken and potential rewards indicated by the increased prospectivity. Conversely, where exploration results are consistently negative, exploration expenditure will decrease along with the prospect's value.

It heavily relies upon the admittedly subjective technical assessment/prospectivity of the prospect by the mineral valuer who, only in exceptional circumstances, is not a geologist (see VALMIN Code, 2005, Clause C22, p 8). The amount of enhancement/diminution of the tenement's overall prospectivity (or exploration potential) due to the exploration expenditure (the expenditure base or EB) is the key.

Note that the MEE method's EB only takes into account the *relevant* and *effective* past exploration expenditure, plus the near-term proposed (and budget-approved) future exploration expenditures (adjusted for any excessive administrative charges or inappropriate expenditure); plus the statutory minimum expenditure commitments, which must be met in

order to retain the tenements. Generally, the prospectivity enhancement multiplier (PEM) chosen for the future expenditure component are unlikely to exceed those chosen for the past expenditure component, for the same tenement. The valuation should be done on a tenement-by-tenement basis.

The MEE method involves applying a premium or discount factor (PEM), which ranges from 0 to 5 (usually 0.5 - 3.0) to the appropriate EB. The PEM used depends upon the success of the exploration to date, and upon an assessment of the future potential of the prospect. The likelihood that the geologic concept, which forms the basis of the current and/or future exploration program, will locate an orebody is important, but obtaining encouraging results from the expenditure is more important. Note that a PEM of <1.0 means that further exploration is not justified and no further value will be added by any more exploration. Drilling must have found intersections of mineralisation to justify a PEM of >2.0 (refer to the PEM Schema below).

LAWRENCE/MINVAL PEM SCHEMA

- 0 No further exploration is justified. The tenement should be relinquished.
- 0 - 0.5 Exploration has significantly downgraded the tenement's prospectivity. The tenement remains at the grassroots stage in spite of considerable past and current exploration expenditure. Further exploration is not justified and a joint venture (JV) based upon a future royalty, or disposal (by sale or relinquishment) are the best options.
- 0.5 - 1.0 Past and recent **exploration has maintained (rather than enhanced) or slightly downgraded the prospectivity** of the tenement. Further field exploration is not justified without deposit model and geological reassessment. A non-contributory JV would be the best alternative.
- 1.0 - 1.3 Further exploration is justified, based on previous exploration results and the potential prospectivity of the deposit, which is based upon the geological model adopted. **Recent exploration has maintained or slightly enhanced (but not downgraded) the prospectivity** of the tenement. Contributory JVs should be considered.
- 1.3 - 1.5 The available **data has considerably increased the prospectivity** of the tenement by identifying and defining geochemical or geophysical anomalies and other exploration targets. Further exploration is justified. Contributory JVs could still be considered, but it may be worth taking it to the next stage alone, if the results are so encouraging.
- 1.5 - 2.0 Recent exploration has enhanced the prospectivity of the tenement. The results from the target area(s) due to past expenditure have identified some drill target(s); and reconnaissance **drilling has found some interesting intersections** of mineralisation. Further exploration is definitely justified to evaluate the target area(s). The PEM rises with the number of targets now involved and economic interest of any intersections.
- 2.0 - 2.5 Exploration has defined a target(s) with **some drill intersections of economic interest** and infill drilling is justified to attempt to define a Resource. Continue exploration alone or negotiate a very favourable JV deal.

2.5 - 3.0 A **small Resource is very likely to be defined by the current drilling** with potential for extension down dip or along strike by further infill drilling and other exploration. Evaluation does not yet include a prefeasibility study. Any JV should include being free-carried to the bankable feasibility study stage.

3.0 - 5.0 A **Resource of variable significance has been defined** with economic features (indicated by prefeasibility study) that make **early conversion to Reserves probable**. Additional Resources are also likely to be found by more drilling. Consider preparation of a feasibility study before selling any equity.

The comparable market value/recent transactions (comparable sales) method (market-based)

This method uses transaction prices of the mineral asset (or previous sales of similar assets) as a guide to the project's value at the relevant valuation date. The mineral assets involved must be truly comparable, eg in terms of location, timing and commodity; and be 'arm's length' transactions to be a reliable source. See Lawrence (2001c) for an extensive review of market-based methodologies.

Values are most commonly derived on the basis of US\$ value/tonne of the JORC Code category of Mineral Resources/Ore Reserves within the tenement that were acquired or sold in the relevant transactions. Using gold projects as a commodity example, the valuation metric used is \$value/ozAu (which is derived from actual project transactions). Loucks and Dempsey (1997) proposed that Ore Reserves on properties could be valued at the exploration stage at US\$7/ozAu; at the prefeasibility stage at US\$15/ozAu; at the feasibility stage at US\$30/ozAu; and at the production stage (say, 0.1 MozAu to 0.5 MozAu/yr) at US\$150/ozAu. For operating mines, they suggested US\$200/ozAu for annual production at around 0.5 MozAu to 1 MozAu/yr and US\$250/ozAu for those producing at >1 MozAu/yr. Rightly, these authors pointed out that the best yardstick value to use in the case of operating mines is the profit margin per ozAu in Reserves, since it better reflects the impact of the gold price at the valuation date.

In a specialist report on 27 February 2001 to KPMG Corporate Finance (Australia) Pty Limited, which formed part of the New Hampton Goldfields Limited's Target Statement in response to the Bidder's Statement by Harmony Gold Australia Pty Limited, it was claimed that appropriate yardstick values to use were <A\$10/ozAu (usually A\$3/ozAu to A\$5/ozAu) for subeconomic resources (low-grade Resources beyond the present economic limits of an open pit); A\$10/ozAu to A\$30/ozAu for reasonably defined Mineral Resources within which the specialist judged that there was a reasonable expectation that Ore Reserves will be established; and >A\$30/ozAu for Mineral Resources for which there is a good likelihood of a high conversion rate to Ore Reserves and/or proximity to an existing plant.⁹

MINVAL in 2008 used values of around A\$50/ozAu for gold in Ore Reserves in non-operating mines (within a range of A\$40/ozAu to A\$75/ozAu); and from A\$5/ozAu to A\$10/ozAu, up to A\$20/ozAu to A\$25/ozAu, for gold in Mineral Resources, depending upon their quality and the circumstances surrounding each mineral asset valued.¹⁰

Most valuation papers that support use of the comparable sales concept always point out that the historical sales have to be comparable (and relatively recent) for its use to be

9. Based upon a forecast spot gold price in 2001 of US\$290/ozAu (A\$483/ozAu at A\$ = US\$0.60).

10. Based upon an actual spot gold price for 2007 of US\$695/ozAu (A\$/ozAu at A\$827 = US\$0.84).

justified. However, this precondition is often ignored in practice because the ‘comparable’ sales being used are clearly not comparable to the Valuation in progress, upon close examination.

A commonly held view is that:

... where there are no anomalies affecting a market, the price at which property changes hands in the ordinary course of business and the market, is usually its true value.¹¹

This is clearly generally true, and underpins the utility of the market transaction-basis of valuation practice (dominated by the deep and liquid real estate property market, for which there are numerous transactions publicly available). However, this tends to obscure a very important scientific fact that each mineral deposit is unique – they are not at all like houses – and the number of transactions is vastly less than property transactions. Hence, the problem is to find truly comparable sales (the basis of real estate property transactions) upon which to base a traditional market or transactional value. Thus, in the presentation of valuations of mineral properties in court, it is critical to emphasise the unique characteristics of mineral deposits, their geological characteristics and their surrounding tenements. Most are purchased because of what they contain (Resources of the commodity to be mined and sold).

A mineral asset’s main worth lies in the quality and quantity of its mineralisation, but orebodies are intrinsically unique in their mineral assemblage, structural setting, depth and mode of emplacement, among a hoist of other things discussed below. This makes simple comparisons difficult. Whilst, Resource/Reserve category estimates also appear to be indisputable facts, different Competent Persons making the estimations may have legitimately different views on their categorisation and quantity/quality. This is because they have reasonably used different grade cut-offs, dilution, mining loss and bulk densities. Again, direct comparison is hazardous.

The individual geotechnical and hydrogeological characteristics, since they affect mining practices or the safety of tailings dams and structures, are likely to be different for each mineral asset sold, too. Each will have different minor constituents in the ore that are likely to influence viable exploitation of the deposit because of metallurgical or environmental concerns. Each will also have different assumptions regarding cut-off grades, dilution, recovery and tonnage/grade estimation methods and parameters and process plant recovery. These differences compromise any claim of comparability.

Mineral deposits are found in different geographical situations with attendant different topography, access, vegetation, climate, rainfall, etc. Even if the mineralisation could be assumed to be exactly the same, in two different locations, one would find widely different logistics to be overcome when developing them; and differences in specific geographical constraints, particularly water supply and the impact of the weather on proposed operations. Any so-called ‘comparable’ deposits will have different levels of existing infrastructure; variable quality, state of repair and appropriateness of existing equipment; and jurisdictional differences, all of which affect the project development costs, too. This will impact on their respective sale prices and values.

In fact, projects always develop at different times in response to perceived supply/demand, but this system is not always economically efficient. This is why one cannot value mineral properties as if all of them will be in production at once, as do many tax authorities

11. See Malcolm CJ in *Commissioner of State Taxation (WA) v Nischu Pty Ltd* 91 ATC 4371 (at 4376), who also listed a Federal Court case and a South Australian Supreme Court case in support of this view.

in the United States. Nevertheless, projects likely to be in production now will be valued higher than those whose development is some time in the future. This simply reflects the time value of money and their greater risk profile, emphasising again the non-comparability of simple sales data.

Inevitably, even supposedly ‘comparable’ sales of mineral assets at the same stage of development will have occurred at different times, in different markets, in different countries or jurisdictions. Some areas of difference are discussed in more detail below.

Valuation dates and premium/discounts

Valuations are made at various times in the economic cycle (boom/bust or bull/bear market involving a premium/discount), so is important to consider if this has had an undue influence on the particular valuation. For example, sometimes a premium has been paid for mineral assets, relative to their underlying value (technical value), because of market demand. This can be beyond any variations due to changes in commodity price. It may be for the level of control of the entity obtained; for perceived synergies in operating or marketing or to unlock other potential; for management strengths; for belief in untested Resource/Reserve upside; for new processing technology; for diversification of risk; for the large size of the entity and its credit rating / access to capital or institutional grade; or for other special advantages that will accrue to the purchaser/seller. Even when transactional valuations appear comparable, they will have been mostly made at dates different to the required valuation date. In such cases, the selection of the most appropriate inflator/deflator to bring them to the required date becomes an issue (see below).

What was bought in the transaction?

Often, important information about a commercial transaction is kept confidential or only sketchy details are released in the public domain. For example, were comparable interests acquired? Free carried interests or royalties may not be publicly disclosed; there may be other rights and interests (eg timber rights, improvements and plant/equipment, or existing sales contracts) or encumbrances/obligations (eg JV financial commitments, environmental restoration, debt, unresolved lawsuits or taxes) retained by the purchaser that have to be stripped out for sales data to be useful; commercial-in-confidence information may have been provided to the purchaser, but not to the market, that influenced the final price; there may be trade-offs or concessions in respect of other tenement/projects that could be even in other jurisdictions; and a premium or a discount may be involved that is not obvious, but which may (or may not) be justified in the valuer’s opinion. These matters exacerbate the difficulties of determining ‘comparability’ of sales data by a valuer. Also, a transaction may be for a specific project that may be inside or outside a corporate structure. This means that the financial envelope (eg hedge book, working capital, value of any other assets/investments, with all adjusted for liabilities) surrounding the project value must be determined as part of the valuation process. These are other complexities to be considered when trying to compare market sales, especially when a valuation is by rules-of-thumb that utilise market capitalisation data from the stock market at a particular time.

Geographical and geopolitical location

Climate and rainfall / water supply all have an impact on a project’s technical feasibility and economic viability, particularly equipment productivity. These parameters will mainly impact on a mineral project’s capital and operating costs. Also, prospective buyers’ perceptions of political risk will always affect a project’s value. The location’s political

stability, degree of labour unrest and general level of personal and property security; its political stability and corruptibility index; its social and environmental agenda; and the permanence and/or nature of its financial/taxation regime are key risk factors that attract a premium (or discount) for relatively similar projects in different locations and jurisdictions. Similarly, different locations have different amounts of infrastructure of variable quality in place. Thus, it will always be very difficult to ensure that sales comparisons are realistic and reasonable.

Mining method

Certain deposit types enable particular mining methods to be used to exploit them. Historically, those that could be mined by bulk open pit methods have enjoyed a preference over those that could be exploited only by more expensive and difficult, selective underground methods. Hence, for the same mineral and similar deposit geometry, those lying at shallow depths are generally more highly valued by the market than deeper ones. For shallow deposits being mined as an open pit, those with the lowest overburden stripping ratios are more valued. Similarly, deposits with the least mining dilution are also favoured. Whilst cost is the obvious reason (eg shallow open pits enjoy capital and operating cost advantages) the relative ease of management and the associated inherent flexibility of mining operations are other non-financial considerations. High margin projects can better withstand commodity price cycles than others, so they command a premium. Thus, one really can only compare sales of projects having similar mining methods and, even then, only those located fairly close together on the cost curve, having similar revenue projections.

Deposit size

The market seems to prefer large, high-grade world-class deposits for reasons other than their obvious commercial advantages. Perhaps it is the comfort in having a Resource/Reserve buffer and the time to resolve any emergent, unexpected problems that is the cause of this effect. Also, management time spent in developing small or big projects is often not markedly different. Hence, for otherwise similar projects, there is a premium for larger deposits, even over smaller, but higher grade ones.

Deposit complexity

The market prefers mineralogical and metallurgical simplicity whenever possible, with minimal product contaminants. Hence, the known preference for say gold deposits over base metal deposits and free-milling gold deposits over refractory ones. Also, those deposits that are structurally complex and ones with geotechnical problems are penalised by the market, since they are more difficult and more costly to mine. Comparisons between apparently 'comparable' projects must include comparable metallurgical treatment, plant design, recovery and final product quality.

Marketability

Those mineral deposits whose products have stringent quality specifications and consequently specialised markets (most industrial minerals); and/or whose buyers are very well organised (eg diamonds and to a lesser extent coal and iron ore) do not have as deep and as free a market as other mineral commodities (like gold and base metals). They tend to suffer a discount in the marketplace. Even when trying to compare like-with-like, it is critical to ensure this is exactly what one is doing.

As noted above, the time the transaction took place is difficult to accommodate in market-based approaches. One has the overall bull/bear market influence to consider. It is also difficult to filter out the overall cyclical nature of metal prices and the foreign exchange relativities. They provide part of the economic envelope around the technical characteristics of a mineral asset valuation and they are not constant, further reducing the comparability of mineral asset sales data. The author has indicated his lack of confidence in the CPI as the best inflator/deflator to bring transaction sale prices to the valuation date for comparative use. It seems, when trying to standardise past transactional values at different times for comparative use, that the change in US\$ commodity unit price is the best way to adjust sale price data to the valuation date.

Rules-of-thumb (yardstick) methods (market-based)

These methods are used where a Mineral Resource remain is in the Inferred category, or where economic viability cannot be readily demonstrated for a Resource assigned to a higher confidence category and available information is limited. They ascribe heavily discounted *in situ* values to the Resources (or small Reserves), based upon a subjective estimate of the future profit value per tonne of ore. This discount, resulting in values of around 0.5 per cent to five per cent (more commonly one per cent to three per cent) of the *in situ* gross metal content of the mineralisation delineated using the spot metal price as at the valuation date. This approach, for example using one per cent (for a gold price of US\$900/oz) is akin to using a valuation metric of US\$9/oz for some Inferred Resources delineated in an exploration tenement; whereas five per cent equates to a metric of US\$45/oz, which is more applicable to Ore Reserves. The chosen percentage is based upon the valuer's risk assessment of the assigned JORC Code's Resource/Reserve category, the commodity's likely extraction and treatment costs, availability/proximity of transport and other infrastructure (particularly a suitable processing facility), physiography and maturity of the mineral field, etc. Clearly, it is a very subjective method whose valuation results depends entirely upon the expertise of the valuer.

Another approach is to use the average of successful explorers' (or the specific prospect's) discovery cost/oz as a proxy for the base value of a prospect that has delineated Resources. MINVAL research (based upon Metals Economics Group and Newcrest Mining data) indicates that in respect of major gold discoveries the 1997 - 2008, discovery cost/oz has averaged about US\$17.22/oz for successful explorers and US\$31.88/oz for all major gold producers (both figures exclude Newcrest's cost of US\$12.72/oz). The weighted average discovery cost/oz (using gold ounces discovered) for all explorers (including Newcrest) is US\$14.63/oz.

Yet another approach is to assign a subjective \$value/unit of area (eg hectare or square kilometres), supposedly based upon prior sales or comparable tenements, but such approaches are not favoured by most valuers as a primary valuation method. It is often used for tenements with perceived prospectivity but little else. As an example, gold values/km², derived from knowledge of numerous transactions, range from A\$2000/km² to A\$10 000/km² (more commonly A\$3000/km² to A\$5000/km²) depending upon the security of tenure of the type of title involved, its size, its prospectivity, proximity to other successful exploration results, etc).

The yardstick method also suffers from lack of real comparability of data, since its values/unit are derived from sales transactions whose comparability must be regarded as suspect from the above discussion. However, Inferred Resources do have value, in the author's opinion – see Lawrence (2012); and Resources generally – see Roscoe (2012).

The joint venture (JV) terms method

This method relies upon the terms of any existing, 'arm's length' joint venture agreement, or sometimes the JV terms for relevant, nearby and/or similar properties. JV agreements typically have staged earn-in phases of expenditure made over time (with later stages at the election of the entity 'farming-in') to earn the interest. The value of equity assigned to the farminor, at any earn-in stage of a joint venture can be considered as the sum of the value of liquid assets (cash or shares) transferred to the seller of the JV interest (farminnee) plus the value of the future exploration expenditure. However, there is normally some initial minimum expenditure commitment by the party farming in (farminor) prior to allowing withdrawal from the agreement. These funds are thus committed, as distinct from the notional expenditure to successful completion of further earn-in stages. This minimum commitment may or may not entitle that party to an earned interest if it walks away from the deal at the first stage. Nevertheless, in the case of a simple deal that is consummated, the value ($V_{100\%}$) of the entire property, where the incoming farminor agreed to spend \$E to earn an interest of one per cent (and does so) would be estimated as follows:

$$\$V_{100\%} = (\$E / I\%) \times 100\%.$$

In a typical staged earn-in agreement, the value assigned to each of the various stages can be combined to reflect the total, 100 per cent equity value, as follows:

$$\$V_{100\%} = \$V_{\text{Stage 1}} + \$V_{\text{Stage 2}} + \dots$$

Note that future expenditures in each earn-in stage following this first year are usually discounted (by say ten per cent per annum, by the current cost of debt or by the calculated actual weighted average cost of capital for the entity) rate to the mid-point of the term of the earn-in phase, to account for the time-value-of-money; and sequentially discounted again by probability factors (in the range 0 - 1, chosen by the valuer) that reflect the degree of confidence that the future period's full expenditure will actually occur in each future stage and each equity position be achieved.

The value assigned to the second and any subsequent earn-in stages will always involve discounted funds, and is likely to require exponentially increasing speculation as to the likelihood that each subsequent stage of the agreement will be completed. Correspondingly, in applying the joint venture terms approach to staged earn-in agreements, it is common to consider only the first stage as the basis for estimating cash value equivalence at the time of the deal and to adopt the end of the initial earning period for valuation purposes. The total project value of the initial earn-in period can be estimated by assigning a 100 per cent value, based on the deemed equity of the farminor, as follows:

$$V_{100} = \frac{100}{D} \left[CP + \left(CE \times \frac{1}{(1+I)^{\frac{1}{2}}} \right) + \left(EE \times \frac{1}{(1+I)^{\frac{1}{2}}} \times P \right) \right]$$

where:

V_{100} = value of 100 per cent equity in the project (\$)

D = deemed equity of the farminor (per cent)

CP = cash equivalent of initial payments of cash and/or stock (\$)

CE = cash equivalent of committed, but future, exploration expenditure and payments of cash and/or stock (\$)

EE = uncommitted, notional exploration expenditure proposed in the agreement and/or uncommitted future cash payments (\$)

I = discount rate (per cent per annum)

t = term of the stage (years)

P = probability factor between 0 and 1, assigned by the valuer, and reflecting the likelihood that the stage will proceed to completion

JV terms are mostly specific to a particular project and so they cannot be realistically used for the valuation of other mineral assets. Knowledge of them may enable the construction of relatively realistic synthetic JVs for comparative use in valuation in some restricted cases, mainly as a sanity check. But, the author fears that the use of conceptual JV terms as a primary valuation tool is inappropriate since it is too open to manipulation and abuse, with a valuer asking at the outset 'What number do you have in mind, then?'

Valuation methodology discussion

The MEE method and the DCF/NPV method of valuing mineral assets generate only a 'technical value' (some call it fundamental value), which excludes any premium or discount to account for market, strategic or other considerations. Inevitably, technical values obtained using these methods appear low in an optimistic (bull) market, but high in a pessimistic (bear) market. Hence, these valuations must be converted to fair market values by considering the current market premium/discount applicable to the underlying technical value (if any).

Note, also, that market sentiment is already part of values derived by the JV terms method, the comparable sales method, and the yardstick/transactional rules-of-thumb (yardstick) method of valuing mineral assets. This is noted here because some valuers forget that they must 'compare apples with apples', with many missing this distinction between the different values obtained by the various valuation methods.

Prior valuations, recent broad economic metrics and share market indicators will be useful in this context. However, despite current market sentiment being clearly relevant, caution must be exercised in the application of any market premium/discount because its relevance can be both transient and highly subjective. In the current economic climate, the use of any such premium must be fully explained and justified on reasonable grounds. Discounts are rarely seen, except in bank-lending transactions where the *real* value is critical, or when the predator in a hostile takeover attempts to minimise the value of the target. Generally, the older the data on which such valuations are based, the more likely it is that this built-in market sentiment must be very carefully reconsidered for its continued applicability in the current market.

For retrospective valuations, any intervening events must not be taken into account. For example, in the classic case of resumptions by the Crown, the fair value of what was taken is the only value required. Consequential damages due to the resumption are not to be included. The relevant and important valuation principle is that only reasonably foreseeable events at the valuation date may be considered. Courts do, however, allow hindsight to operate when establishing the reasonableness of past predictions, etc.

Since a reliable and acceptable valuation of a mineral asset largely depends on the results of a prior technical review and assessment of these assets, only professionals who are appropriately technically qualified, suitably experienced and highly reputable should undertake them.

However, the reader is again reminded of the considerable subjectivity of the valuation process, depending as it does upon individual professional judgement. Remember, too, that all value estimates are time dependent and are particularly influenced by the market conditions existing at the valuation date.

Any attempt to quantify the chance of achieving exploration success is clearly speculative. Also, any predicted profitable returns from mining development scenarios are not guaranteed to occur. When coming to a conclusion as to the value of a mineral property, the author relies upon reasonable and considered assumptions based on his knowledge of the owner's past and present experience (reputation and competence) and exploration success to date, including the current quality and status of its technical database and its exploration or development team and management; the financial and staff/time resources provided to that team. Similar assumptions are made about future events, particularly commodity prices and the ability of the owner to produce and market product of the required quality to achieve budgeted profit levels.

Understanding valuation risk

General economic factors and changing societal requirements have to be considered as part of the risks in a valuation. Factors that affect a proposed mining development include inflation, currency fluctuations and interest rates; industrial unrest; land access (and within Australia, the Aboriginal land rights/native title process); environmental controls and standards; and taxation and royalties. They all affect the owner's ability to fund a project's development and to raise additional working capital (either as debt or equity) for exploration, development and mining operations during the mine's life. Lack of certainty about the future actions of any government (at local, state and federal levels) is also important in this context.

Valuers must incorporate appropriate probability factors in their valuation methodology (and fully explain their selection) to address all relevant risks. The use of a single discount factor to address unspecified, numerous probability factors is unacceptable to the author. For an outline of the risks inherent in assessing mineral ventures, see Lawrence (2004 and 2005; and 2008). For a review of the role of due diligence in project assessment and valuation, see Lawrence (1997a and 1997b; 2008).

Valuation approaches

When valuing a mineral property, the author attempts to use as many valuation approaches (market, income and cost) and methods as are appropriate for its development status and the purpose of the valuation, though there have been instances where only one technique has been considered suitable. The values generated by each approach (usually based upon the average of the methods used) are compared to identify if there is any consensus of results (ie a grouping of values that cluster around a particular level). This clustering suggests the most rational level at which the mineral asset should be valued and gives some comfort as to the reliability of the valuation.

Most commonly, the author accepts a specific value generated by a particular approach as his preferred case value (most likely scenario) for the mineral asset, rather than use the average of the values obtained by the various approaches employed. However, the range of values attributed to a mineral asset, which extends from a low case (pessimistic scenario) value to a high case (optimistic scenario) value, should encompass the two extremes obtained by all methods used. Hence, it is only very rarely that the preferred value is the simple arithmetic average of the low case value and the high case value. The author urges caution in accepting simple arithmetic means as the preferred value since there is rarely any logical justification for doing so.

On some occasions, when the data permit, the author has averaged the average values obtained by each valuation approach (income, cost or market-based), to derive the preferred value.

Use of the DCF/NPV method (part of the income approach) is still not favoured in many jurisdictions in the US, particularly in valuations for litigation purposes, with preference being given to the market approach. However, most transactions involving developing and operating mines tend to have as their fundamental basis a DCF/NPV analysis. Few would feel comfortable claiming that the best way to value such mines would be to simply average the NPVs for some individual supposedly similar developed or operating projects and then apply the result. Also, many valuers see no problem in deriving average transactional values/unit for use in a current valuation, even though acquisition prices are commonly based on NPVs.

The author believes that the NPV method should never be applied to the valuation of a mineral property that is only at an exploration stage, based on the hypothetical cash flows from a postulated exploitation scenario. However, it is appropriate to calculate the conceptual NPV of the income stream, which might be generated by leasing the project or obtaining a royalty stream from it; by grazing livestock or crop-farming the surface; or by considering a non-mineral highest-and-best use of the property (eg residential development).

At this point, it is worthwhile to reflect upon exactly what value is being determined by DCF/NPV analysis. Valuers tend to consider before or after tax values only in the context of the DCF/NPV method, with a general preference for determinations of after-tax value. It is the author's view that other valuation methods implicitly derive after-tax values, although taxation issues do not feature in most of them. This means that such values can be averaged to obtain a market value (provided the NPV is adjusted for the market premium/discount; otherwise, the data would not be comparable).

Of course, some owners can use tax losses and structure their affairs to minimise the impact of corporate taxes, but others cannot do so. Hence, it should be clearly stated on what taxation basis the fair market value is determined. This is another reason why care must be taken when using project sales data as a comparable basis for assessing value. The 'comparable' projects may be in different places subject to different taxation regimes, in any event.

The author would suggest that whatever value one chooses on technical grounds, like those described above, sovereign risk must be factored into the selection of the final A\$/value/ozAu used. There is a reluctance to pay as much for a gold mineral asset located in a region with socio-political problems compared with one where the fiscal and security regime is benign. Similarly, tenements located in proximity to environmentally sensitive national parks or where there are as yet unresolved native title or Aboriginal sacred site conflicts, have less value than ones without such problems to address. The proposed introduction of carbon and mining taxes in 2012 will also have an impact.

THE INTERNATIONAL CHALLENGE

Each jurisdiction has its own rules and requirements that must be respected. However, the increasing globalisation of the minerals industry makes it essential that international standards of project assessment and valuation, as well as reporting standards, be as similar as possible from the viewpoints of the relevant national regulatory and national professional bodies. The same applies to the terms used. Even though the IVSC terminology is well developed (mainly for real estate), the well accepted, historical terminology of the minerals industry cannot be totally disregarded.

Also, professionals must be able to practice across international and inter-state boundaries. Hence, the accreditation (registration) and the maintenance of continuing professional

development of the authors of valuation reports, as well as the ability to effectively discipline them (ethics codes), should be similar between international jurisdictions to facilitate the overseas mobility of these minerals industry professionals. The US still has not followed the general approach of other mining nations, notably Australia, Canada and South Africa in the move to standardisation of the relevant codes.

See Lawrence (1999b and 1999d; 2000c; 2001a and 2001b; 2002a and 2002b) for further discussion of these issues and a discussion of the need to ensure that the developing international accountancy and valuation standards are suitable for the minerals industry worldwide.

KEY OBSERVATIONS

The general valuation essentials contained in this section should assist mine managers dealing with mineral asset valuations, but they cannot be read in isolation. Nevertheless, a key principle is that all valuations are time and circumstance specific and relate to a particular valuation date. Most transactions are unique events. The valuation also may not be the price ultimately accepted and paid. Mineral valuation is very subjective and the probity/independence and track record / experience of the valuer are paramount considerations in the reliability of the valuation produced.

Mine managers, irrespective of their original professional training (eg mining engineers, geologists, metallurgists, etc) must continually keep in mind the reality that many technical professionals will have to have relevant input to the identification of the Mineral Resources/Ore Reserves that underpin the reasonableness and reliability of the assessment of the technical feasibility and economic viability of a project and its ongoing existence. This becomes more critical in the valuation of the subject mineral asset, despite technical professionals having increasing competence in financial analysis today. Having available demonstrably adequate environmental expertise and the ability to deal with social/cultural issues and any objections to development from civil society can often outweigh purely technical considerations.

That said, having an understanding of The AusIMM's Ethics Code, Code for Consultants, JORC and VALMIN Codes all provide assistance in assessing or producing mineral asset valuations. But they are only a necessary but not sufficient requirement for a mine manager. Common sense, communication skills and an appreciation of dispute resolution principles are other critical skill sets to acquire. Above all, apply due diligence principles to proposed valuations and associated issues to ensure that they are rational and can pass the Reasonableness Test. However, it is almost impossible to identify and compartmentalise all the inputs into decision-making by mine managers and provide all the 'silver-bullet' answers in any one book to deal with mineral valuation.

6.2 PROJECT EVALUATION

The mine manager's role and interaction with projects can be many and varied with influencing factors including the size and complexity of the project, its location relative to the mine, the size of the company, and company procedures for project development, evaluation and execution.

Projects can be classified by complexity and scope into minor, medium and major and many larger mining companies will have definitions around such classifications. For

smaller and newer companies that may be yet to develop a guideline the following criteria is provided for the mine manager's guidance:

- *minor* – small projects easily managed by a single person, completed within a year from inception to completion, low interaction with site or external stakeholders, suggested less than \$1 million investment
- *medium* – for projects requiring oversight, multiple part-time team members and/or full-time manager, up to two years from inception to completion, some external impact and more complex stakeholder interactions, multiple parallel contractors required, capital of up to \$5 million for a small company, perhaps \$20 million for a large company
- *major* – significant capital investment, high degree of stakeholder involvement and interaction with other site facilities or off-site business units, external stakeholder involvement, higher degree of risk, time frame exceeding two years (risk of turnover in project leaders).

Most major projects (same order of magnitude as the mine) will be handled by dedicated teams, which in most cases will be external to the mine, but preferably will have close involvement with the mine manager and his/her team should they relate to its future operation.

The mine manager's role rarely involves leading project studies or their evaluation, but may involve roles such as the project sponsor or project director. For these roles, the mine manager may need to source project funds and key personnel, and champion the cause. For larger and high expenditure projects, the mine manager may need to form a steering committee (or be co-opted onto other project steering committees) of independent company officers collectively experienced in all the project's facets to provide oversight and quality/accountability.

Where the mine manager is responsible for provision of key personnel, their full time involvement may be critical to the project's success. The mine manager is cautioned that part-time team members who have operational duties will often not be able to spend the required time on the project given the urgency of operational requirements compared with the importance of the project work. Other project-related success factors include identifying the stakeholders that will be potential customers, contributors or otherwise impacted (including perception only) to ensure their input is incorporated.

The mine manager's involvement in the evaluation of a project will generally also be as a higher level reviewer. Various forms of evaluation will be ongoing throughout the project but the mine manager will usually only be consulted in the outputs of these evaluations. Traditional evaluation methods include financial measures, contribution to strategic objectives and risk management. Complex projects will often be performed under a rigid study phase approach and will include formal toll gates for high level authorisation to continue between each stage.

For minor projects, the mine manager may be the authorisation level required, but for larger projects, the manager may find his role being to communicate upwards, and to external stakeholders, the value of the project. In order to 'sell' the project, the manager must have ownership of the value of the project, and will need to communicate this in higher forums. Higher level company personnel must also go through an ownership process to sell the project further up the line, or to authorise it at their level. Often this process can appear to involve some conflict, and generate defensiveness in those unaware of the process they are experiencing. The manager's role here is not to defend so much as assist in the understanding and ownership of the project, and comfort levels of the risk profile at the

higher levels of the company and in some cases externally. Requests for further information are usually to assist in higher level comfort and understanding, rather than extension studies in areas thought to have been missed.

For the mine manager's guidance new discoveries that lead to greenfields mines typically involve around a ten-year period from discovery to full production. Underground mines take longer than open pit due to the nature of underground mine development and risk. While several sizeable open pit mines have achieved full production in as little as six to seven years, many other mines have taken considerably longer from discovery to production, particularly where the economic case is unclear or not significantly compelling.

6.2.1 The project study process

The project evaluation process is a continuous one from first concepts of a project through to investment approval (and beyond). The goal of this process is to ensure that if implemented the project will achieve one or more corporate objectives, which may include financial, production growth, technical improvement, safety, environmental, community benefit, etc. Therefore evaluation criteria may include financial or production outcomes, risk mitigation, or other subjective criteria, and should be individually defined for each project under evaluation. Projects should therefore be assessed against these criteria from the outset.

Many companies have project evaluation guidelines; however, evaluation guidelines are just that – guidelines. There is no substitute for a well-rounded experienced project management team with sound judgement to determine which parts of a study evaluation should be in greater depth, or are not relevant.

Many minor to medium-size projects are generally engineering type projects involving modification or construction of fixed plant. New or significant extensions to pits or underground mines are typically medium to major in complexity and involve a substantial expenditure in mining activity in addition to fixed plant construction. These two types of projects can be defined therefore as 'engineering' or 'mining' projects.

ENGINEERING PROJECTS

Engineering projects are typically dominated by their content of mechanical, civil and/or electrical engineering, or perhaps a software solution. They generally include a construction (or delivery) phase and are often either an in-house managed engineer, procure and construct (EPC) or a full engineer, procure, construct and manage (EPCM) approach. This often has a different culture to operational mining cultures, and has a temporary presence on the mine site from construction to the point of handover from commissioning to operations.

Typical stages of engineering projects include:

- *Initial proposal* – resulting from technical or operational investigations that define a problem, desired outcome and the potential value in its achievement. The proposal could also originate from a risk assessment, community feedback or reputational improvement.
- *Project definition* – the definition includes the first scope of work, approximate time frames and resources required to meet the value proposition, and the estimated cost to complete.
- *Preliminary design* – definition of functional requirements, preparation of technical specifications, first engineering designs, basis of detailed cost and schedule estimates but not in sufficient detail to place orders or begin construction.
- *Detailed design* – generation of detailed packages for tendering, 'for construction' drawings, detailed cost and schedule to complete the project.

- *Execution planning* – development of the execution plan, procurement of project resources, definition of quality assurance and quality control, contract awards, safety management plans, supervision teams, etc.
- *Construction/delivery* – supervision of physical activities, contractor management, expediting of important items, schedule and cost management.
- *Commissioning* – pre-acceptance testing (no-load, wet testing, first materials), training of operators, development of maintenance plans, and finalisation of operating procedures.
- *Handover and close-out* – handover of project, demobilisation, completion of a punch list of outstanding items, finalisation of documentation, lessons learnt, evaluation of project deliverables and its management.

Many of the stages outlined above have alternative terms used throughout the industry for similar stages in the project cycle. The terms selected above and in the next section have been made to avoid conflict between differing meanings for the same terms.

Table 6.2.1 summarises these steps with order of accuracy of capital costs, and suggested contingency allowances, which reduce as the uncertainty reduces. The ‘tollgate’ approvals stages will usually be defined by company policy; they typically occur prior to the approval of significant expenditures and are based on the likelihood of the project deliverables being achieved compared with the risk of further investment. In the absence of a company policy, the mine manager is advised to seek reapproval before:

- project definition to ensure any resources are allocated to the highest value projects
- detailed design due to the cost of design work, authority to tender sections of the work and resources needed for execution planning
- construction, as this will represent the bulk of the expenditure and trigger any physical interactions with other operations or external stakeholders.

TABLE 6.2.1
Engineering project summary of stages.

Engineering project phase	Estimate of cost at completion	Capital spend at time of estimate	Suggested budget contingency
Initial proposal	-30% to +50%	<0.5%	30%
Project definition	-20% to +40%	2% - 5%	30%
Preliminary design	-15% to +30%	5% - 10%	25%
Detailed design	-10% to +20%	10% - 20%	15%
Execution planning	-5% to +15%	20% - 25%	15%
Construction/delivery	-2% to +10%	25% - 100%	10%
Commissioning	±1%		
Handover and close out	±0%		

Typical key roles for engineering projects include:

- *Project initiator* – person who identifies the need and defines the underlying problem that the solution sought will address. Success of the project is dependent on the clear definition of the project’s aim.
- *Project owner/sponsor* – person who ensures the budget and resources are made available for the project investigation, and must have sufficient delegated authority for the level of

the project expenditure. These may be different roles for complex projects and will often involve the mine manager.

- *Project manager* – person appointed to manage the process of the solution investigation, design and evaluation, construction and handover within budget and on time. As the skill sets required in the various phases may change then this person may be changed at various phases of the project.
- *Project team* – technical and project management resources, in-house and contractor, part time and full time.
- *Project steering committee* – for more complex projects to ensure the project is achieving its aims and is responding to the risks identified. Committees should include the project manager, sponsor/owner, and sufficient knowledgeable persons of status not directly connected to the project to maintain an honest and objective overview, which at times can require some courage when projects are struggling to achieve their desired deliverables.

MINING PROJECTS

Most mining project studies fall into the major or medium categories. Logan, Grant and Pratt (2006) describes the process of mining project development as a pipeline from exploration to project approval, with only a few initial prospects reaching a successful feasibility conclusion. The structure of the studies recommended is similar for the study stages with the depth that each section is applied varying between the study stages. Study components should include:

- *executive summary*
- *business and sustainable development* – country and location setting; legal issues; project ownership; government and community, including the project approvals/permitting process; human resources; health, safety and training; and environmental topics
- *technical* – geology, including drilling programs and Mineral Resource estimates; geotechnical; mining, including layouts, methods, equipment selection, schedules and mineable resources (Ore Reserves); metallurgical, including ore characterisation, test programs, process flow sheets, plant design, tailings disposal; infrastructure needs, including power, water, road and rail access, housing and accommodation needs and maintenance plans
- *financial and commercial* – operating and capital cost estimates; marketing; risk management; and financial evaluation, including revenue estimates, cash flow, working capital, taxation, sensitivity analysis and financial outcome measures (net present value, internal rate of return, return on capital employed, free cash flow, total cash out, etc)
- *future work plan*: next study stage (scope of work, schedule, resources, budget, drilling proposals and tenders, technical investigations, risks to be mitigated, etc) or for a final feasibility study a project execution plan and an ongoing operations plan.

Stages of mining project studies

With the above framework in mind, typical stages of mining project studies include the following.

Concept (or venture) study

A basic project outline to establish whether there could be a viable project and an indication of potential value in comparison with the funding requirements to investigate further. Often

various forms of concept studies follow new discoveries and outlining of new resources while further drilling is justified. Budgets for concept studies are relatively small and time frames limited to months, and these studies are usually independent from resource drill-outs and often based on scaled historical data. Study deliverables include an evaluation of business strategy fit, possible financial outcomes, high level risk assessment, and scope to complete further work on the opportunity potentially including the basis for a scoping study.

Scoping study

This is the first assessment of a business case. A scoping study should consider and compare all of the possible mining methods, process flow sheets and scales that might be possible and evaluates the most practical and technically viable options to take forward into a prefeasibility study. The study scope will include:

- a fatal flaw assessment
- considerable resource drilling (majority of resources to be in the Inferred category by the end of the study)
- sustainable development issues identified, including workforce numbers and potential source
- specific political and community engagement requirements, environmental issues and future data collection needs
- technical (resource characterisation and configuration, mining layouts and first pass optimisations, head grades, process flow sheets, saleable product characteristics)
- operational (power, water, workforce accommodation and site access requirements)
- financial (operating and capital costs based on factored quotes and similar projects, schedules and evaluation of the business case).

Key outputs should include:

- recommendations for a prefeasibility study (if justified); scope of work, schedule and budget
- major technical challenges and risks to be mitigated
- environmental baseline data collection plan
- drilling proposals and tenders.

Prefeasibility study

The prefeasibility study is the first detailed study phase that defines the key project parameters. The technically feasible options are refined to determine the best option and all major data should be collected in this stage. Resource, geotechnical and metallurgical sample drilling should be largely completed to enable definition of a largely Measured and Indicated Resource and preferably preparation of an Ore Reserve. Pilot plants and exploration declines may form part of a prefeasibility stage, or may form part of an extended prefeasibility stage before a feasibility study is justified. The full scope outlined above should be studied, with an emphasis on trade-off studies for technical issues and risk mitigation for non-technical designs. Community engagement should be well established, with issues having management plans in place. Environmental data collection for an environmental impact statement (or local equivalent) should be well advanced as should permitting and approvals preparations. The final recommended project outline will not be optimised, but should be sufficiently developed and refined that no significant changes are required in the next stages, and the robustness of project economics are understood. Costs should be based on factored budgets and budget quotes.

Key outputs should include:

- recommendations for a feasibility study (if justified): scope of work, schedule and budget
- optimisation and risk issues
- environmental studies and community engagement actions
- any further data required, including in-fill drilling proposals and tenders.

Feasibility study

This is covered in detail in Section 6.2.2. In this phase the technical and economic viability are demonstrated. Minimal additional data collection should be required with the emphasis being on optimising studies and risk mitigation; no further significant options should be considered and at the end of the process the design is frozen. Environmental impact statements (EIS) and permitting/approvals processes are initiated (generally a project is not publically announced or works on the ground commenced until all permitting is completed, even though a feasibility study may be completed and the project moved into a detailed design stage). Optimisation of the mining layout, process flow sheet, site layouts, etc is completed with results of trade-off studies being judged by their relative impact on NPV first, and other criteria when NPV shows no significant difference. Only Measured and Indicated Resources should be used and a diluted mineable resource derived, which can become an Ore Reserve upon approval of the project's construction. Engineering designs should be preliminary stage or better (20 - 30 per cent of project engineering), with costs being based on a combination of first principles, firm quotes, engineering estimates and material quantity take-offs (including growth factors). Outputs include the first draft of the execution plan, including the budget and scope of work for the detailed design phase and identification of long-lead-time items such that early orders can be placed. The feasibility study report will become the control document that the project is subsequently compared against and therefore it must contain all of the calculations and reasoning, and must be laid out to allow auditing and for JV partners and financiers to justify their involvement.

Detailed engineering design

The final engineering is completed with outputs being technical documents, 'as for construction' drawings, updated material quantities, reconfirmed costs and bid prices, definitive cost estimate and project schedule with details on work breakdown structure and work packages.

Procurement/construction/development

The physical project construction and mine development phase is integrally linked with detailed engineering, procurement (plant and equipment, supplies, contractors, contract management, expediting, schedule impacts), construction (supervision of physical activities, contractor management, schedule and cost management) and management (EPCM teams, owner's teams, contractor's facilities, etc). A mixture of mine development by in-house and/or contractors may be used to develop the mine to a production-ready state, which is often not well managed by typical EPCM organisations and it is recommended that owner's teams manage this part of the project. Outputs include physical progress and reporting against schedule, cost, scope and quality criteria. Construction of discrete times is considered complete when ready for no-load testing.

Commissioning

This requires detailed planning and risk management as various locations become energised. It includes pre-acceptance testing (no-load, wet testing, first materials), training of operators, development of maintenance plans and finalisation of operating procedures. Ideally the owner's team operators will have been employed in time to assist with construction and participate in commissioning before signing over the assets to operations.

Handover and close-out

Handover of project occurs when the project has been commissioned and is running to expectations (throughput and quality), contractor and owner's team have been demobilised, a punch list of outstanding items has been compiled, documentation has been finalised, outstanding claims and warranty issues have been dealt with. This is also the point where lessons learnt, an evaluation of project deliverables and an assessment of the management work can be completed. Reporting this information can often require some objectivity and courage by the report authors to identify areas and issues that could have been handled differently.

Summary

Table 6.2.2 summarises the mining project study steps with order of accuracy of capital costs and suggested contingency allowances, which reduce as the uncertainty reduces. The equivalent application of the above to mergers and acquisitions would be target identification as scoping study level, screening due diligence as prefeasibility study, full due diligence and execution planning as feasibility, and deal and business integration as construction and commissioning.

TABLE 6.2.2
Mining project summary of stages.

Mining project phase	Engineering/design completed	Estimate of cost at completion	Capital spend at time of estimate ^a	Suggested budget contingency
Concept study	<1%	-30% to +50%	<0.5%	50%
Scoping study	<3%	-20% to +40%	2% - 5%	35%
Prefeasibility study	10% - 15%	-15% to +30%	5% - 10%	25%
Feasibility study	15% - 25%	-10% to +15%	10% - 15%	15%
Detailed design	>65%	-5% to +10%	15% - 20%	15%
Construction/delivery	>95%	-2% to +10%	99%	10%
Commissioning	100%	±1%	100%	
Handover and close out		±0%		

a. Capital spend estimates are inclusive of resource drilling expenses.

Tollgate approvals should exist before scoping, prefeasibility, feasibility and construction stages. An additional tollgate will often be appropriate between feasibility study and detailed design depending on the proportion of capital investment that detailed engineering design may influence and the risk that cost estimation may be incorrect, leading to a financing shortfall from feasibility approvals. Projects involving a high degree of non-mining EPCM content, for example a new open pit mine in a remote area (requiring minimal pit preparation and prestripping), where the majority of spend is on fixed plant, foundation preparation,

concrete, steel and piping, or infrastructure such as access roads, power station or grid connection, water connection or bore field, rail link, etc would be well advised to include the detailed design tollgate. On the other hand, an underground mine in a greenfields environment, where fixed plant EPCM work may be less than 20 per cent of the budget, may assess the risk of not including a detailed design tollgate tolerable.

The detailed design stage may also be completed in parallel with the procurement and construction stage, particularly where the proportion of infrastructure is a relatively small part of the project budget. In cases where schedule timing is critical, these parallel activities may be worth the risk of cost increases during detailed engineering.

The roles a mine manager may be involved with include as the project owner, project sponsor, potentially seconded into a full-time project manager roles, or as the member of a steering committee, including for non-related projects.

6.2.2 Mining feasibility studies

The purpose of this section is to provide guidance (to mine managers) on the preparation of feasibility studies and to identify some of the common issues that arise in their preparation and comment on how these might be managed. The areas addressed include:

- the feasibility process and its components
- development of plan for a study
- management of stakeholder engagement and review processes
- identification of risks and opportunities.

The preparation of feasibility studies is a topic that is well covered in minerals industry technical literature, either specifically under its own heading or the more general topic of project evaluation. This body of work is supported by well-developed protocols and processes for feasibility studies, developed by most of the significant minerals-based consulting businesses and producers intended for the preparation of the studies they might require. Also, more recently in some jurisdictions a prescriptive outline for the public reporting of these sorts of studies or 'technical reports' has developed (eg the Canadian NI43-101 code).

The feasibility study is a ubiquitous element of just about all mineral projects, ie they are demanded for most projects by either or both internal and external stakeholders to the project.

However, despite their seemingly universal use any quick survey of the literature on mining projects shows that the majority of minerals projects underperform against the operational and financial targets defined by their feasibility study. It is for this reason that the following section is included in this volume.

WHAT IS A FEASIBILITY STUDY?

As a minimum, a feasibility study is an internal final assessment process (West, 2006). However, while often true, this statement alone does not provide any depth to meaning of the term feasibility study required to appreciate its implications for a project. Alternatively, reference is made by Shillabeer (2001, p 435) that a 'feasibility study is a comprehensive estimate of the time, cost and profitability of a project' and that it can demonstrate this profitability has acceptable return with an acceptable risk (McCarthy, 2006).

A feasibility study should not be confused with a business plan for a project. The two serve different functions; as indicated in this section, a feasibility study is about the definition of

a project, whereas a business plan outlines the actions needed to take a project from idea to reality (Hunter *et al.*, 2009).

The Canadian Institute of Mining, Metallurgy and Petroleum (CIM, 2010) definition for a feasibility study describes it as a comprehensive technical and economic study of the selected development option for a mineral project that includes appropriately detailed assessments of realistically assumed mining, processing, metallurgical, economic, marketing, legal, environmental, social and governmental considerations, together with any other relevant operational factors and detailed financial analysis, which are necessary to demonstrate at the time of reporting that extraction is reasonably justified (economically mineable). The results of the study may reasonably serve as the basis for a final decision by a proponent or financial institution to proceed with, or finance, the development of the project. The confidence level of the study will be higher than that of a prefeasibility study.

This definition is useful because it shows a feasibility study in its true light; that is as part of a continuous evolving process of data collation and knowledge building, rather than an end in itself. Recognition of this process is fundamental to the potential future success of a minerals project. This process is an iterative staged approach to studies and entails developing response to a series of layered questions. It is for this reason that mine managers, and prospective study managers for that matter, are cautioned against falling for the temptation to forego one or more study stages that precede a feasibility study.

The integrity of the process is important and, as shown in Table 6.2.3, each of the stages has a different role. There is a need to recognise that as the study process progresses there is a change in the balance of intellectual environment; the initial focus is one of strategic thinking and seeks to consider all avenues to enable the work to define the goal for the project. Later in the process, and certainly in feasibility, the majority of the effort is directed at identifying the tactics that will deliver the goal defined by earlier work (Kear, 2004).

A significant observation made regarding the study stages for a project is their relative relationships with influence on project value and the cost. This is illustrated in Figures 6.2.1 to 6.2.3.

TABLE 6.2.3
Study stages and expected outcomes (after Mackenzie and Cusworth, 2007, p 67).

Study stage/central questions	Expected outputs
Scoping study: • What could it be? • Does it make sense to pursue this opportunity?	• Several viable business cases based on a Mineral Resource
Prefeasibility study: • What should it be? • Have I analysed enough alternatives? • Have I identified the optimum project configuration?	• A preferred business case • Ore Reserves • A clear record of the basis for rejecting any of the discarded options • A plan for undertaking the feasibility study (optional)
Feasibility study: • What will it be? • What risks will this project involve? • What rewards will this project provide? • Have I presented an investment case that is unlikely to vary significantly?	• Detailed business case and facility plan (design and estimate) Assessment of project risks and opportunities • Project execution plan

FIG 6.2.1 - The leverage of early work (after Mackenzie and Cusworth, 2007, p 67).

FIG 6.2.2 - The ability to create or add value (after Mackenzie and Cusworth, 2007, p 67).

FIG 6.2.3 - The degree of definition in study stages (after Mackenzie and Cusworth, 2007 p 72).

As a study progresses some consideration is also required as to whom the evolving project knowledge might be relevant, such as stakeholders, customers, or new members to an expanding study team as a project moves through successive study stages towards implementation. Not all of these groups will require the same level of detail; however, they all need information to undertake their respective roles. For the feasibility study stage in particular, this aspect has special significance for two reasons. The first one is defined by the feasibility study's relationship with the implementation stage of the project, where perhaps the largest and most transient group of people are involved with the objective of building the operation defined by the study. The second is the implications for a study if third parties are involved, or likely to be involved, as a lender or project investor. The presence of a lender or investor triggers a requirement for a higher standard of verification for the study. Both these reasons have the capacity to impose on the feasibility study specific requirements on the scope addressed in a study.

Involvement of a third party as an investor or lender may give rise to a requirement for detail on the:

... proposed project gearing, revenues and proposed loan servicing and payback, all of which should be in the feasibility study. A prospective banker also requires evidence that a company's management team has the ability to effectively manage and coordinate the various phases of the project. They may also require reports from independent sources, covering selected areas already covered in the feasibility study. They use these independent reports both for initial due diligence purposes and for project monitoring during the preproduction phase (West, 2006, p 117).

The imposition or emphasis of these additional aspects on a feasibility study is often flagged by assigning the preface 'bankable' to the feasibility study title; ie bankable feasibility study.

A feasibility study for a mining project is simply one part of the journey that generally commences with discovery or recognition of a potentially significant mineral occurrence and concludes the commissioning of the project as an operation. Along the way a potential project progresses through a staged study process. At the end of conceptual/scoping and prefeasibility stages a decision may be made to commit further funds to continue investigation and evaluation. At end of a feasibility study the refined form of the project is clear and set for a decision to commit to implementation.

The outcome of this process is not certain and significant decisions can only be made based on a judgement of well-constructed and clearly presented options and estimates; very few of the important numbers are exact, no matter how many decimal places are shown.

A successful study may conclude that further investment is not warranted until certain other non-project related criteria are met. This can often be a difficult emotional time for a study team that can see that there is no likelihood of the project continuing, and understanding the right time to halt the process and complete the documentation can be challenging.

DEVELOPING AND UNDERSTANDING A STUDY PLAN

Irrespective of the stage of the study work it is useful to have from the start of the work a plan for the study; ie how to deliver the scope for the study. Depending on the type of study; scoping, prefeasibility or feasibility, the study plan will address the components listed in Table 6.2.4 in increasing levels of detail as the process progresses.

TABLE 6.2.4
Study components.

1. Business and financial	2. Implementation	3. Legal and commercial	4. Technical
a. Financial analysis	a. Project execution plan	a. Ownership	a. Geology
b. Strategic fit	b. Operations management	b. Socio-political	b. Geotechnical
c. Market analysis	c. Information, knowledge and technology management	c. Regulatory/permitting	c. Mining
d. Risk and opportunity management	d. Human resources	d. Legal and tax	d. Metallurgy and processing
e. Capital cost estimate	e. External relations	e. Contracts	e. Infrastructure
f. Operating cost estimate			f. Engineering
g. Capital funding			g. Environment and community
			h. Health and safety

Two practical elements give balance to this process. The first is planning for each of the proposed areas of work within a study built around:

- definition of the issues covered and the scope of work addressed
- identification of all the inputs; available sources of information, data and precedent activities
- definition of the outputs; deliverables required and identification of their relationships or links to other study activities or decisions
- outlining the estimated time required to complete the work and resources required
- discussion of hold points for the work and review processes applicable
- providing an estimate for the cost of the work.

A draft table of contents or so-called ‘straw man’ for a study is a second practical process that serves to ensure the study ‘gets where it is supposed to go’. The purpose of the table of contents is to illustrate and describe what the study will deliver when completed. The relationship between these two processes; plans for work areas and the table of contents, ‘bookend’ a planned study and may be a little dynamic as the study progresses. However, the dynamic nature of this relationship only serves to illustrate why both are useful in planning and managing a study; one defines what is to be done and the other where the work is going. With only one in place it is easy for a study to lose its way. The consequences of a study losing its way are loss of focus, gaps in the work and insidious scope change that is often associated with drifting time lines.

The executive summary for a report is frequently the only part of a study that some people will read and it is for this reason that its preparation merits some thought. Irrespective of the approach taken to the structure of the study or the study stage the executive summary represents the highest level of report, providing in ‘plain English’ an outline of the context for the work, the approach taken and all the material outcomes, including the identification of any significant risks and opportunities for the project. The use of ‘plain English’ with limited technical language ensures that key aspects of the project are really accessible to the widest possible audience.

The individual sections that form the body of the report are prepared from summaries of individual expert areas of work referenced in the preparation of the section. These expert areas of work are available as the primary appendices to the study report. Any material not referenced directly in a section and assembled by the study team to support or referenced in the expert reports should be included as secondary appendices.

In the early stages of a study, scoping/conceptual, strategic thinking is important, whereas as the study reaches feasibility, provided the early stages have been properly completed (Kear, 2004), the work is increasingly tactical. A feasibility study should be about defining, refining and building the detail required for the preferred approach for a project to ensure required levels of accuracy are met; all the major decisions should have already been made by this stage (Kear, 2004). Shillabeer (2001, p 435) shares a similar point: 'a feasibility study and major project team is no place to change the strategic concepts'.

As study progresses much of the effort is directed at defining the options and alternatives that are preferred and how to progress them into the next stage, it is easy to miss the equally important task of documenting discarded options. The importance of documenting the discard option is to demonstrate that rejected options are convincingly discarded, based on objective criteria, so they cannot 'bounce back' into contention later (Logan, Grant and Pratt, 2006). This process provides a reference to the requirements that need to be met for a previously rejected option to return to contention.

The study manager, in addition to planning (schedule and budget preparation and tracking) the work of a study and managing the work content to meet the requirements of its scope and table of contents, must also consider two related but quite different areas; keeping the stakeholders informed, and ensuring that the work completed is of a standard that is commensurate with the level of work required for a particular study stage; scoping, prefeasibility and feasibility. The purpose of stakeholder communication is to provide internal stakeholders in the project with an opportunity to contribute to the study's preparation. Specifically it is an:

- information session for those not involved, directly or indirectly, in the study to inform them of progress to date
- opportunity for input by stakeholders; both scope and process
- forum in which to flag any additional issues not taken into account in any of the work done to date.

For these purposes, stakeholders are broadly defined as those people in roles within a project owner's organisation who:

- could be expected to have knowledge or insights that the study should be aware of
- need to be aware of a study's general direction and progress
- are not involved in the study itself.

The stakeholder consultation process is distinct and separate from a formal project review of a study discussed later in the study process evaluation section.

IMPORTANT ASPECTS OF THE STUDY PROCESS

Study preparation and establishment are crucial to scoping and framing the work. The aspects listed below cover some of those that are frequently important to the outcome of a study:

- Well-defined business outcomes and clear measurable methodologies.

- A project scope that is well defined. Scope change and scope creep, including unfunded omissions; extension studies and additional drilling will eat project funding and take additional time, and may distract the focus of the team.
- Assumptions, where used in any stage of a study need to be clearly stated and where possible the work required for their confirmation included in subsequent study stages. This is especially important for those assumptions that are likely to have a material bearing on study outcomes.
- A clear work breakdown structure (WBS) is equally applicable in the study stages of a project as it is during the implementation phase of a project. The early use of this common project management tool enables ready comparison between successive study stages and the allocation of accountability for completion of work and its supervision. The combination of a WBS and good cost and time estimation is essential to understanding how long the study will take, what resources are required, who has accountability for each section of the study, how its progress will be measured against cost, work-hours and time, and what interdependencies exist within study subtasks. Each task should include base cost and time estimates, and growth factors for unknown minor items that are discovered during the progress of the study (it is impossible to foresee all requirements). This information will define the study time frame, critical path schedule and required funding.
- Managing consultants or subconsultants; requires a clear scope that there are limits on their ability to continue to generate costs for the study beyond an agreed estimate without a formal approval process.
- The design criteria provide a common starting reference document for the preparation of a study and provide vehicle for knowledge transfer to the next stage of the project; in this sense it is an evolving document. They encapsulate and summarise the owner's requirements and philosophy together with known input data. Examples of inclusion in this document are references to:
 - standard glossary of terms and their abbreviations
 - common contextual information needed for the study
 - applicable standards, codes and legislations/regulations
 - risk management tools and requirements.
- Allow adequate contingency funding for cost and volume underestimation, unexpected study outcomes or complications, or additional opportunities identified in the course of the study. It is recommended that a minimum contingency for a well-defined study should still be in the order of 15 per cent to 20 per cent, as many circumstances can change over a long-term (measured in years) study. Having to ask for additional funding without an additional value improvement is rarely a pleasant experience.
- Include realistic growth factors in cost estimates to avoid future execution cost over-runs. A growth factor makes allowance for additional quantities above the design estimates for wastage, over-excavations, small redesigns, latent conditions, etc. The major areas that require growth factors include preparations of ground for foundations; foundations; concreting, steelwork and piping in general, electrical cabling and connections, communications and control systems including code writing, etc. In underground mining it may be an allowance for additional mine development metres, ground support, vent walls/minor constructions, production redrilling, overbreak haulage, etc. In open pit mining some allowance for minor slope failure management, wall support and additional pumping may be prudent. With contracting it may be allowances for minor variations, delays and day works.

- Ensure that any options or alternatives identified in the study that are discarded are properly documented, as described in the previous section. Studies, particularly in the early stages, rely on a discipline of considering all conceivable options for establishing a business case and equitably evaluating them. The contribution of senior experienced personnel is important (Kear, 2004) in this process.
- Data collection phases are often the limiting factor in study time frames. Data collection usually includes resource, geotechnical and metallurgical drilling, and metallurgical testing, which many downstream studies rely on. Therefore drilling is a core activity for the early phases of a study stage, and project scoping should also include drilling proposals and tenders.
- Peer reviews and audits at appropriate points in the study. Team members will often 'own' the study and become so close that they may overlook deficiencies. Peer reviews and project audits (covered in the study process evaluation section) are an opportunity for learning and maintain objectivity within the team.
- The inclusion of new technology in a project links with understanding the owner's appetite for risk and the project's ability to deal with the consequences of the failure of any new technology deployed to meet expectations. The question is; how good is Plan B and what will it take (cost) to deploy?
- Fast tracking the approval of a critical path project implementation activity that can materially reduce the time to establish an operation prior to full project approval through early commitment to activities like data acquisition, engineering and procurement.
- Predetermined freeze points for the project outcomes, such as major plant capacities, transport routes, etc.
- Inclusion of all non-technical and commercial aspects including sustainable development and stakeholders. The study will need to understand the needs, concerns and desires of all stakeholders, including government departments, community groups, potential customers, landowners and the general public. Modern sustainability criteria demands that projects do not compromise the ability of future generations to meet their needs, which should be a core evaluation criterion in every major project.
- As much as developing a plan for a study is important, identifying the human resources, the people who will be engaged in the work requires due consideration. At issue here is understanding the mix of capabilities, experience and temperaments that are needed to complete a given stage of the study process. The project team should include full range of competence in all aspects of the study. The tendency otherwise is to underrate the depth and importance of aspects of the study that are not well represented on the team. This can lead to shortfalls in the understanding of risks and requirements in these areas of a study.
- A clear understanding of project risks and issues as they develop, including well-documented issues registers and risk matrices with mitigation actions, responsible officers and time frames.
- Holistic study thoroughness builds on the definition of the study and the combined competence of the team including consultants. Each section must be completed with diligence in relation to the risk or discovery of unknown issues; superficial studies may expose the execution phase to unexpected complications. Experience suggests that each issue that arises costs an order of magnitude more to resolve with each major stage of a study, eg execution over feasibility study.

- Preparation for the next phase of a study or its implementation is simplified if as many as possible of the key personnel of the next step in the project are fully imbedded in the previous stage. This allows them to own the content via their included input and alignment to a common vision. Handing over a project to a new team almost always allows some form of reinventing the wheel and modifications of scope to the new personnel's preferences. Support for the human side of this process is greatly assisted by ensuring that effective processes are in place for knowledge transfer; knowledge management and document control.

The underlying themes of this section are captured in Table 6.2.5, which is presented as a concise checklist to assist a mine manager in the various roles and relations with studies; as leader, a contributor or a supporter.

TABLE 6.2.5
List of lessons learnt preparing feasibility studies (after Shillabeer, 2006, p 440).

Number	Lesson
1	Don't begin the feasibility study until the project scope is defined and the economics have been optimised.
2	Work constantly to enhance the credibility of the feasibility study. Don't skimp on expertise.
3	Reserves should be validated before the feasibility study is well advanced.
4	Minimise the work done outside the task force.
5	Consider the personalities of the individuals involved on both 'sides' before agreeing to a pepper and salt arrangement.
6	Produce and distribute the project description, summary execution plan, summary procedure manual and design criteria as early as possible. Keep these documents current and enforce them.
7	Establish an economic model early and update it. Use it to 'push back' against cost increases that are not accompanied by schedule or revenue enhancements.
8	The study manager should define at the outset and enforce his or her requirement for design criteria.
9	Use process flow diagrams (PFDs) in all areas where there is movement of materials or people.
10	Construct the project-wide mass and water balances and periodically update and elaborate them.
11	Leave plenty of time to review and check results.
12	Use only proven and familiar software.
13	Involve the owner's representative (OR) in informal initial design discussions before work begins, even when a study is completed 'in house', to ensure that policies are respected and the views of the business's operational group are respected.
14	Use milestones to record progress and challenge people. Ensure that everyone knows about the current milestones.
15	Establish at the beginning with the OR the general policy towards change.
16	Plan from the beginning to be technically audited and arrange for it to be done during the study.

6.2.3 Mining project evaluations

The scope and criteria of the evaluation¹² are defined by the full set of project deliverables, as defined at the outset of the project and updated at the start of each study stage, within the corporate framework of the assessing entity and company project study guidelines.

12. The term 'evaluation' used in this context relates more to the term 'audit' than 'valuation' in the VALMIN context. Audits have a different management purpose and are separate to 'valuations', which imply a sale transaction of some form. Specialised audits are referred to later in this section.

The most popular view of project evaluation is of the financial or economic aspects, as this represents the 'score'; however, there are many other evaluation techniques that assess the foundations that the financial outputs are based on. One of the key success factors in the evaluation of a project is the degree to which the project outcomes are defined, as this will determine what the project is to be benchmarked against. Criteria should always include risk (design, operations, construction, technical, unknowns, financial environment, operations, maintenance, products) for safety, environmental, financial, business reputation, legal compliance, etc.

Logan, Grant and Pratt (2006) describe some project risks and shortcomings that evaluation processes ought to detect and correct, and compares the study process to a pipeline of business development phases from exploration to execution approval. To repeat an earlier point, a successful study may conclude that further investment is not warranted on technical or financial grounds, possibly until certain other non-project related criteria are met, or perhaps divested.

The evaluation can only draw conclusions as accurate as the least accurate input into the study outcomes, which in turn are the inputs to the financial models. Therefore, the evaluation process really begins in the early stages of a project and continues throughout the study process to the final designs, financial modelling and the understanding of project sensitivities and risk profile.

STRATEGY AND RISK EVALUATION

Strategic review

The highest level review of a project compares the corporate or business unit strategy against the project outcomes to ensure there are no conflicts with any aspect of a proposed scope. How the project contributes to the corporate strategic objectives should be clearly understood and communicated within the project team.

At the start of any project stage the strategic objectives defined in the project scope should be evaluated for degree of success and likelihood of achievement. Another key criterion is the ability of a company to resource the development, planning and execution of the project (Logan, Grant and Pratt, 2006). Numerical objectives, such as minimum hurdle rates, are usually relatively clear; softer objectives may require a discussion to explain the degree of achievement. Projects that target more intangible outcomes will have to be assessed on individual merits and little guidance can be given in a generic explanation.

Long-term projects should be continuously evaluated against continuing corporate strategic fit as corporate strategy may change over time in response to both internal and external influences. Projects may be on the books for long periods of time during which corporate strategy may vary with other discoveries, acquisitions, company scale, being taken over, selecting a new geographical or commodity focus, etc. Other strategic goals may also change, including financial criteria, risk tolerance, or changing community and government expectations regarding a particular project.

Fatal flaw analysis

One of the first evaluation steps in a study process is a fatal flaw analysis, which is a high level generic risk assessment focusing on major risks and potential 'show stoppers'. Risks can be grouped according to fit with corporate strategy; potential stakeholder involvement; legal compliance; political/sovereign; environmental; process technology; financial; commercial; and operational risks such as mineral content, mineability and saleability of product. The

review group should include knowledgeable and experienced personnel for every aspect involving the project, and be encouraged to overrate the risk if in doubt so that follow-up studies can assist with a more informed assessment of the risk. Naturally, if a show stopper is identified and proven to be real, the project should be terminated.

It is recommended that this assessment be completed as soon as practically possible and before the commitment of significant funds, but at the latest before the scoping study is completed. Actions to investigate and mitigate high-level risks can then be incorporated into the scope of work for the next phase of the study process and risks reviewed depending upon mitigation achieved. The analysis may be reviewed during subsequent phases of study; however, it is often more effective to transfer the risks identified into a more detailed risk matrix environment and use the fatal flaw process as a reminder to indentify new risks.

Each company will have different risk appetites and strategic objectives, and so it is recommended that individual companies develop their own list of key risks to evaluate. The list for a multinational company evaluating international greenfields projects will be more comprehensive than a smaller single-country-focused organisation.

Risk management

Standard risk management analysis is covered in Chapter 10.5 (Risk Management). The risk assessment process during a study is a continuous one, with the study having an emphasis on quantification of the risk and mitigation alternatives. The risk register and associated mitigation plans form a significant part of the project evaluation process. This is an effective process for evaluating the potential of the project to achieve its technical and financial objectives. The risk appetite of the corporate entity will frame the risk profile, and a sensitivity analysis will also demonstrate the impact of risk issues.

Risk management can begin with the fatal flaw list (or may well precede it), but will move into more specific risks as the project investigation unfolds. Risks are often recorded in a risk register, including the hazard scenario; uncontrolled likelihood, consequence and risk score; plans and specific actions and accountable persons to mitigate the risks; and the mitigated likelihood, consequence and risk score.

Recorded risks will include many standard operational risks and project execution risks in addition to technical risks, and will also consider risk areas such as the competence of the study process itself (due diligence and appropriate experience). Many companies use some form of project management standard or guideline, which should include a holistic set of criteria that each stage of a study can be judged against to ensure thoroughness of the process.

From a project evaluation perspective the financial risks are often the main focus, including internal project aspects as well as market-based risks to the financial outcome. Other key areas for mining projects also include the perspectives of ensuring business continuity or business growth in the future, and social licence to operate. The design features and management plans that are developed for risk mitigation are progressively incorporated into the project plan, and ultimately into the project execution plan. Trigger action response plans (TARPs) are a valuable risk tool to determine in advance what steps should be taken at defined risk levels and progress outcomes to guide future management teams as to when intervention is required. TARPs should outline the potential risks, consequences faced and the circumstances that will contribute to the hazard scenarios with the mitigation strategies required at each point to minimise the impacts.

During the study process many risks can be avoided, isolated or engineered out, and the reduction in risk profile should be evaluated. Risk profiles that do not reduce with each study phase should be clear warning the project is facing difficulties and its financial and technical viability will be hard to demonstrate, much less achieve. A mine manager should be aware of the risk profile of any project that they are involved with, and understand the implications of the number of high risks.

Risks with high or extreme ratings need to be discussed in any application for funding, including the mitigation strategies and likelihood of managing the risk. A project with a high number of high risk ratings will be more challenging for the same investment level, and may require an additional risk premium over the normal hurdle rates to offset the expectation that some of these risks will not be fully mitigated.

STUDY PROCESS EVALUATION

Peer reviews

One of the most effective study process control actions is the convening of regular reviews by panels of independent experts, internal or external, with at least one person for each study discipline or subdiscipline to assess the progress. This will enable a 'fresh eyes' approach to understand the limitations, risks and opportunities, advantages and disadvantages, to ensure that a comprehensive study approach is being achieved with no omissions.

Reviews should cover all aspects of the study that have been progressed since the previous review, including actions arising from that review. Feedback is sought regarding the adequacy of work, the potential for errors that could affect the viability of the project, or any risks that had not been identified or adequately addressed. In addition to technical review, the cost base, execution plan or future scope of work, EPCM costs, level of cost estimate accuracy, the risk register and mitigation plans, and the degree to which non-physical or financial objectives are met should be included in the review scope.

In the absence of any corporate guidelines, reviews should be considered with each stage toll gate, and in between at approximately every six months from prefeasibility onwards. Reviews should be considered at scoping study stage for complex or high investment level projects. The scope of work for the following stage should be presented as part of the final output of the previous stage, and therefore included in that peer review. Reviews are most useful when there is still sufficient time remaining in the study to investigate issues raised and reach a resolution or action plan during that study stage.

Success factors for peer reviews include the facilitation by an independent facilitator who has no technical knowledge and therefore cannot steer a technical debate, but can ensure that the debate is adding value. Prereading made available to reviewers will enable the technical content to be better absorbed prior to the sessions rather than in the sessions. Outputs from the review should include a summary and an action plan (who will do what by when) to follow up on issues and risks raised.

The process and role intended for the reviewer is one of objectivity, with the aim of providing a pragmatic review of the standard of work completed for the study. The reviewer should not, however, be drawn into the work of addressing any deficiencies that might be identified in the work. Invite more reviewers than necessary as non-paid reviewers (perhaps colleagues from other companies) may not be available or may pull out at short notice. Reviewers require careful selection, based on the following abilities:

- to be able to express views without causing offence, and to ensure that the questions that are appropriate to a particular study stage are asked of the study team and that their answers are robust and supported by data
- to be able to provide constructive input and provide innovative ideas
- are competent and independent (ie not directly involved in the work) of the study itself
- possess significant experience that is relevant to scale and technology likely to be required, based on practical and not just its theoretical application
- have a profound understanding of specialised area – from first principles.

Project audits

A project audit is a specialised audit process carried out by an independent (in-house if available) project audit team looking at processes and risk management. This is not a peer review of content, but a more objective analysis of project processes and depth of due diligence. Specific items include project reporting, use of risk management tools and project tools such as earned value, project finances, contingency fund management, peer review effectiveness, etc.

TECHNICAL EVALUATION

Evaluation of alternatives

Technical evaluation of alternatives occurs constantly from concept to feasibility with the emphasis first on broad brush technical potential, with items such as location, mining methods and basic flow sheets. As the study moves into feasibility stage the evaluations are of smaller scale and often associated with trade-off studies, where the options studied must first be capable of achieving the outcome sought. Technical evaluation then moves to items such as cost estimates and schedule risks.

The early technical evaluations are made by competent teams backed up with peer reviews. Study reports must include evaluation of technical risks of each major option and its potential viability, even if only to dismiss the concept with an effective explanation, for example due to a fatal flaw, excessive risk or perhaps excessive cost.

As the study moves into fine-tuning of ideas to improve functionality and cost, including capital versus operating trade-offs, the study team will need to define its own criteria for technical improvement, including risk of failure to achieve defined outcomes. It is suggested that in order to evaluate trade-offs on a holistic basis, that improvement in NPV be the rating tool. One downside to NPV use is that it discriminates against an expansionary capital spend where the cash flow does not occur for more than eight to ten years, for example a deeper mine to allow for future production. While experienced study teams may understand the logic of further investment in such a case, it will not have a compelling value using NPV alone.

For instances where a number of interacting options are to be optimised, each with a number of potential values or settings, the number of possible combinations or permutations to investigate can make the decision process very complex to the point of impracticality. For example, if there are six options each with five choices, then there are 30 cases potentially to investigate. This situation can be simplified by isolating each option and examining its effect on NPV from its possible values. Where the NPV results clearly indicate an optimum value, then further permutations involving that parameter may not be required. An experienced project team will understand where interactions must be taken account of, for example production rate and cut-off grade, and therefore where project cases cannot be reduced.

Where NPV analysis cannot conclude a clear optimum value, a range of values must still be considered. The use of five data points from five values for an option should enable graphical observation of the optimum, trends near the optimum point, and values that further use of will not add value. Often in cases where the NPV is not sensitive to the actual value selected, technical factors and risk mitigation dominate the value selection process. Carr *et al* (2009) includes a practical example of these issues.

Physical outcomes

Most physical or production outcomes are measurable numerically and can be compared with expectations and similar projects. Estimation of Mineral Resources and derivation of Ore Reserves are covered by the JORC Code (JORC, 2004), including modifying factors. Ore Reserves should include conservative ore loss estimates and recovery factors. A mine manager over-viewing Ore Reserves should consider the ore loss estimates, and also consider the concept of 'risk tonnes', where the last quantities from stopes and pits are planned to be mined, but not included in final project estimates due to the risk that they may not be recovered.

It is important that mine production and development schedules that are achievable and benchmarked to other similar operations with a sufficient learning time ramp up. The risk that the start-up schedule is achievable should not be underestimated. It is useful to benchmark the start-up to other operations as the unidentified issues that cause a learning curve with new operations are not always fully identified during the feasibility process. The mine manager is warned that one of the larger technical risks of projects at final feasibility stage remains schedule risk.

Benchmarking estimates for time, costs and performance metrics derived by a study is important; they provide a means of understanding why your project is different or at least how it compares with similar projects or operations. The role of this sort of exercise is to understand your project by reference to outcomes achieved by current operations or estimates for other projects. Material difference, better or worse, should be rationally explainable.

The ultimate output of technical evaluation is a demonstration of the technical viability of the proposed project, and the associated risk profile.

FINANCIAL EVALUATION

The basis underlying financial evaluations should be examined against quality of cost and physical estimates. Sensitivity analysis is often used to look at how robust the project appears to be, with the more sophisticated sensitivity analysis methods such as Monte Carlo simulations producing a more holistic view.

Financial evaluation

The financial outcomes for a project are a product of many inputs: costs estimates made from first principles, price enquires or benchmarks to develop costs for operating, project and expansionary capital and sustaining capital for the life of the project. Estimates are required for treatment recoveries, losses in treatment processes and transport, and payable formulae to derive estimates of saleable products and revenue. These combine with mining and process schedules to derive cash flow estimates, enabling the determination of standard measures (see definitions below) such as net present value, internal rate of return, simple and discounted payback period and maximum negative cash position.

Many organisations will have existing guidelines and policies for evaluation of feasibility work and investment approval processes. For situations where such guidelines do not exist it is recommended that the mine manager consult the Guidelines for Technical Economic Evaluation of Minerals Industry Projects (see Appendix 1) at the outset of such studies in order to integrate the concepts from the start.

The initiative for the development of these guidelines was Card (2009); this paper outlined a number of shortcomings in financial evaluations; many of these are tied to poorly laid out spreadsheet models that become ‘black box’ instruments that provide little opportunity to check for errors and understand the logic applied. The working group that developed the guidelines consulted widely within AusIMM membership to develop what is considered one of the most comprehensive tools for financial evaluations yet developed for minerals projects. Card (2012) goes on to explain the underpinning principles of these guidelines and mine managers are strongly encouraged to download and absorb them. In his explanation of principles Card also makes the point that the financial modeller should be integrated into the study team and be fully accountable to the study manager, rather than providing a service while based in an outside department.

Not all mine managers have a high degree of financial training, and so the following definitions are provided:

- *Weighted average cost of capital (WACC)* – a weighted average of various sources of funding including equity, and various forms of debt where interest tax deductions can make debt cheaper than face value. In general, equity is required to make a return higher than the risk free rate (generally accepted as government bonds) in line with the industry and company risk profile with returns as dividends and capital growth, and will usually be a higher rate of return than most forms of debt when backed with valuable assets. ‘Junk’ bonds and other debt of last resort will have a high cost of capital, and unless making profits, there may not be a tax deduction for interest to reduce the cost of debt capital.
- *Net present value (NPV)* – the sum of the annual cash flows discounted for time value of money at the WACC.
- *Internal rate of return (IRR)* – the discount rate required to achieve an NPV of zero, and is a basic indicator of the rate of investment return. Longer duration projects will generally have lower IRR values.
- *Hurdle rate* – a rate of return above the WACC that takes account of general and specific project risks that projects must return at or above in order to be considered for approval.
- *Payback period* – a continuous summation of cash spent on the project less the cash incoming. The payback period is the time in months (or years) for cash to net back to zero. This does not account for time value money and therefore has less meaning the longer the time taken to achieve payback. A more useful measure would be to use discounted cash flows; however, this is not a popular measure.
- *Total negative cash position* – the total cash outlay being expansionary capital, and preproduction operating expenses capitalised, and early operating costs before the project becomes cash positive. Project finance must be sufficiently large to ensure this cash outlay is available, plus a working capital margin, plus an allowance for slower project ramp-up and lower early revenues. Projects and companies have failed in the past due to a cash crisis (a lack of cash) after having achieved the majority of their project outcomes.
- *C1 costs* – the cash costs of producing a single saleable unit of production, for example an ounce of gold or a pound of metal. Costs include transport, royalty payments and by-product credits, but exclude capital costs, depreciation and amortisation.

- *Earnings before interest, tax, depreciation and amortisation (EBITDA)* – revenues less operating costs.
- *Earnings before interest and tax (EBIT)* – EBITDA less depreciation and amortisation charges.
- *Net profit after tax (NPAT)* – EBIT after interest, financing expenses and taxation, being the official profit figure.
- *Return on capital employed (ROCE)* – EBIT divided by assets employed.
- *Return on equity (ROE)* – NPAT divided by average shareholder equity for the period.

While many of the above measures are used simultaneously, most projects are usually ranked financially on NPV first, and IRR or ROCE as a secondary measure. The scarcity of capital available within a company will also come into play with the best projects being financed first, and some that meet hurdle rate may still not be approved.

The evaluation can only draw conclusions as accurate as the least accurate input into the study outcomes, which in turn are the inputs to the financial models. Financial models determine a single figure for each financial rating, a sensitivity analysis looks at the effects on these values should there be a change in a key input such as cost, saleable product or metal price.

Sensitivity analysis

Sensitivity analysis is often used to look at how robust the project appears to be and to give some guidance on the risk that the project may not achieve its financial projections. A sensitivity analysis can be performed on a number of levels. The simplest form takes a ± 10 per cent or ± 20 per cent variation of key inputs and examines the resulting change in NPV one value at a time. The results may be represented visually on a spider diagram (graph with NPV on vertical axis and change in input parameter on the horizontal with several parameters graphed together) or tornado graph (a vertically stacked graph with change in NPV on the horizontal axis and bars representing each parameter stacked vertically). Usual subjects of analysis include operating and capital costs, commodity prices, exchange rates, recoveries, schedule ramp-ups, etc. In simple terms such analysis tells the examiner what the effect of a ten per cent or 20 per cent variation in input parameter will cause, but does not indicate how likely this is to occur.

Monte Carlo simulations

Examining the likelihood of key input parameters moving within anticipated ranges is a more in-depth sensitivity analysis as it uses likelihood of input variation. Each parameter must be researched to arrive at a view of high and low values, and the probability of each. In theory a probability distribution can be described for each, but in reality they are often just described as triangular distributions for simplicity's sake. Using Monte Carlo simulations (using commercially available spreadsheet add-in tools) a distribution of NPV outcomes can be generated and each parameter and an expected profile of NPV values created. This allows a deeper understanding of the impact of that distribution and therefore how material the NPV's sensitivity is to it. The profile of NPV results is used to assess the degree of sensitivity of NPV to that parameter.

A final stage of complexity combines all of the sensitive input distributions into a single analysis and produces a statistical range of project outcomes. From this output a mine manager can interpret the percentage change that the hurdle rate will be met, the likelihood that the project will make a loss (expressed as a percentage), and the up-side potential.

Van Leuven (1998) provides an example of where Monte Carlo analysis was used to compare two mining methods with the recommended method having a slightly lower indicated NPV, but with a more confident and tighter range of potential NPV outcomes.

While this provides a more holistic understanding of the anticipated range of project values, there are a number of limitations that should be understood. First, several of the input variables may vary together as related inputs but this is difficult to simulate. Second, the current methods usually only select one value from each distribution and use that for all years in the cash flow series rather than a new selection for each year of the cash flow. Third, the accuracy of the distributions is a foundation for the outputs and is very difficult to derive and should be viewed as an approximation rather than a defined profile. Carr (2002) describes in more detail some of the limitations of determining meaningful probability distributions by mining professionals, and the ability to still gain a more holistic view of a project within these constraints.

This type of stochastic analysis will provide a deeper understanding of the financial risk profile of the project; however, of itself it cannot reduce the risk. The final step will be to review the sensitivity outcomes in light of existing risk management and mitigation strategies, and to recommend further risk mitigation alternatives if appropriate.

There are several more advanced analyses that are considered beyond the normal level of sensitivity analysis that the mine manager may hear of. For economic variables that are linked in time, it is possible to use a mean-reverting random walk, for example for commodity prices with exchange rates partially linked to prices according to historical covariance. These outputs ensure some observed co-relationship is maintained, and may also be used to sample sequentially related values for each year's cash flow.

Should it prove possible to build critical decision points and production alternatives into a project model it may also allow real option valuations. This may allow assessment of any additional value in cases that have flexibility to respond to changing economic circumstances during the life of the project; however, these are very advanced techniques, and the outputs are still limited by the accuracy of any input project estimates, methodology quirks and probability distribution functions.

6.3 PROJECT APPROVAL

6.3.1 Introduction

MAINTAIN CLEAR OBJECTIVES

Managers all wish to 'get it right the first time'. The success of a project depends on the preparation given to its establishment and to maintenance of clear objectives. Leadership involves clarity of a long-term rather than short-term view, successfully communicating objectives that are modified in light of competence (knowledge with experience), maintenance of reaching shared objectives and involvement of individuals.

Market assessment and preliminary feasibility has probably been established. However, project approvals should proceed while working concurrently with financial and technical developments. Iterations are likely and should be a welcomed way of testing objectives, options and measures to achieve effectiveness and efficiency. This is more than an exercise in environmental protection.

This section deals with site evaluation and operational parameters in more detail and is written for mine or mining project managers. Details of the geology and geography are collected, tested, analysed and evaluated against other data and information. Progressively, external interactions take place. The outcomes of these are not always going to go the way the organisation would wish; expect some issues or concerns to be raised with a higher level of interest than anyone would have expected.

In succession, a concept plan, then an environmental impact statement (EIS), then an application for development consent/approval will evolve. At the same time a mining operations plan (MOP) must be developed. As part of this MOP, subject-specific management plans will emerge and will contain more detailed material in relation to a specific topic, for example explosives management. These management plans will need to be cross-referenced to the MOP. An example of this will be a site security plan to be attached to an application for an explosives magazine licence. Other examples are environmental management and safety management plans, both of which are commonly required to be formalised and flow from the MOP.

PERSONAL DEVELOPMENT OPPORTUNITY

The opportunity for personal development should be taken by getting involved wherever possible in project approvals. The experience will prove invaluable in understanding how to enlist the support or to motivate others. Corporate standards, preliminary feasibility and budget parameters will be better understood as well. Mine management must always have a depth of the practical realities of capital, operational and revenue budgets, as well as external views and input. In other words, take the opportunity to develop a 'structured mind' beyond the mere technical areas.

For example, a systematic approach to safety requires consideration of the four components of work, namely the managed working environment (both the physical and the cultural); equipment and materials as well as operational impacts; people (including contractors), and processes/procedures. For each of these four components the aim, plan, implementation, monitoring and improvement need to be outlined. This could be shown in a matrix as shown in Figure 6.3.1.

System outline	Aim	Plan	Implement	Monitor	Improve
Managed working environment					
Equipment and materials as well as operational impacts					
People (including contractors)					
Processes/procedures					

FIG 6.3.1 – Systems outline – showing the four components of work and five continuous improvements elements for a system.

Note that the five phases across the top of the matrix in Figure 6.3.1 are analogous to the phases of the project; analyses, design, construction, monitoring and adjusting, and finally review.

Safety could be used as the example because most mine managers and management staff have become well experienced in managing safety. The most fundamental requirement is to have safe systems of work. Such a way of describing a systematic approach to safety makes it ‘memorable’ and easier to communicate – rather than being an encyclopedia that sits on a shelf until needed. This approach can be extended to other management plans. For example, an approach to environmental management can utilise similarly the five continuous improvement components across the top of the safety system outline. Likewise, the four components of work can be utilised, although the ‘equipment and materials’ component could be swapped for ‘short- and long-term environmental impacts’, with equipment and materials as a subset of these impacts. The main advantage in developing compatible models for systematic approaches is to evolve integrated systems. However, such models also facilitate spontaneous communication in all sorts of situations.

ESTABLISH AIM / OBJECTIVES / AGREED OUTCOMES

The formalisation of aims/objectives or agreed outcomes is not an easy task, but the sooner it is done the better the result. It can, of course, evolve. Doing this is a skill that requires clarity of purpose, which will be highly advantageous when ‘negotiating’ with anyone, so it is worth the effort for management in practising the skill. The more formally this is required to be expressed, the more likely the *aim* will comprise:

- the broad objective
- scope
- definitions
- references.

Management easily understands objectives such as ‘tonnes, cost and grade’. More experienced management, especially those who have dealt with people outside the mine, will readily see the extensions to these simple objectives. ‘Tonnes’ relates to anything that needs to be achieved – the ‘what’. Furthermore, experienced management understand that ‘how’ is often just as important as the ‘what’; so ‘cost’ involves both finances and timeliness, and ‘grade’ is the quality of the action and how it is perceived by others. Intriguingly, ‘cost’ should be seen as a profit centre rather than as a typical cost centre – illustrating the need for a mature mind when using this in a project planning sense. A variation of ‘tonnes, cost and grade’ is recognised by contractors in their expression of success – ‘on time, on budget and as per plan’ – although this might encourage a short-term view of ‘what’s best for project’ as opposed to the longer-term perspective often required to ride through cycles in resource prices – hence the ‘tonnes, cost and grade’ model, which is more sustainable.

Doing this sets the scene for developing a *plan*, which is the next of the five major steps.

Sustainability in a changing world requires some courage as well as adept skills in managing, and managing change in people, planet and profitability. Nurturing the right culture and reputation must be appreciated before starting consultation.

APPROVALS PHASES

At a basic level, the common phases in project approvals and these are analogous to risk management:

- identifying issues and concerns – hazard identification – leading to a project ‘concept’ to be discussed with key government agencies, who will offer suggestions

- proposing precautions – risk assessment – leading to an EIS for public display, attracting detailed critique for tightening controls
- stipulating control measures – risk controls – leading to license applications, hopefully with more of the sort of objectives, outcomes or process-driven management plan specifications rather than specific controls that last the length of the operation and are not ‘alive’ or incapable of changing as determined by agreed monitoring and review consultation *processes*.

6.3.2 Plan the project approvals phase

CONSULT AND COMMUNICATE

Consultation and communication will dictate how easy it is to manage approvals phases and the ongoing operation.

Prepare and begin early. Don’t begin before understanding the geology and the orebody, nor before understanding the geography. The collection of information, collation and analyses of data, testing of assumptions and controls and identification of potential changes and their significance has already been done – but not finished – when consultation commences. Skills in consulting and communicating are essential – and are likely to be refined during project approval stages. Keep clear objectives in mind and be adaptable. Try to anticipate and prepare for criticism, what may seem like harsh criticism, even personal attacks.

Levels of consultation and communication will need to match the other stakeholder. Preparation will keep the project off the defensive. Indeed project personnel must not be overly defensive. They will experience the whole range of maturity in communication, progressing from ‘vulnerable’ towards ‘resilient’ communication relative to the maturity of those being consulted or involved in communication. It might be necessary to help stakeholders come up to a level of maturity by experiencing the successive levels of maturity.

Flexibility and adaptability are required, because stakeholders don’t do things to suit the project; they do things that suit themselves. ‘The people you least want to talk to may be the people that you most need to talk to’ and this will require a level of comfort in hearing or drawing out options and coming up with a reasoned, balanced and proper response. ‘So, what are our options?’ might be a useful phrase for some project representatives to remember.

Negotiation also involves follow through – acting on data and information not on whim. ‘Plan what you do and do what you plan’ – with proper and communicated adjustments along the way.

Participation and communication are key to good risk management. A handbook (HB327 – 2010 Communicating and Consulting about Risk) has been published by Standards Australia on consultation and communication about risk management. This is significant.

This Handbook is a companion to the Australia/New Zealand Risk Management Standard (AS/NZS ISO 31000:2009 – formerly AS 4360) and the Risk Management Guidelines (HB 436:2004). It uses academic research and practical experience to flesh out the ‘Communicate and Consult’ part of the risk management process. It was written to help people who manage risk.

The handbook goes on to state:

The risk management process requires a thorough understanding of the organisation’s objectives and the internal and external context from which risks arise. Communication

and consultation help to ensure that the context is considered broadly and all stakeholder interests are considered. As part of the context the criteria used to make decisions about risk are defined, and these should take into account the views of the stakeholders identified as part of the review of internal and external environments. This analysis also provides the backbone for the communications plan.

Maturing levels of consultation and communication might be illustrated in Figure 6.3.2. In this figure Hudson (2001) has illustrated a pathway that provides a model for safety culture improvement.

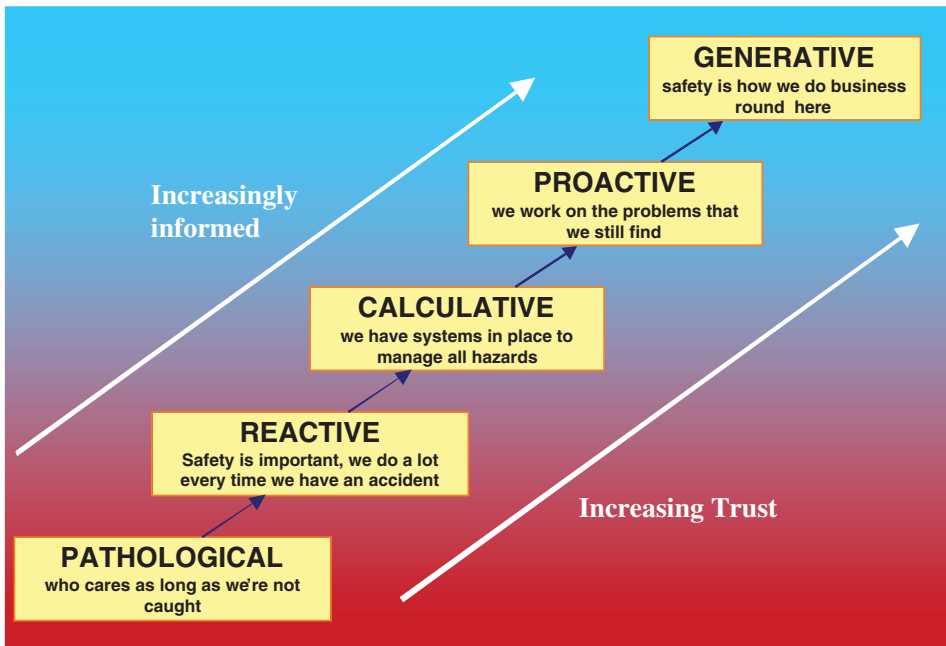


FIG 6.3.2 - Hudson's 'Maturity Model' illustrating the importance of communication with evolving culture (source: Hudson, 2001, reproduced with the kind permission of Crown Content Pty Ltd).

While the 'maturity model' may be applying to safety, the same could be said for all aspects of the operation including risk management, consultation and communication or any other particular aspect. 'Vulnerable' mines deny the existence of hazards and risks. A regulatory response is to set standards of detailed actions and limits, to conduct close checks of performance at frequent intervals against these prescriptive requirements and to issue 'on-the-spot-fines' and stop work orders.

If a mine is lucky enough to survive a serious incident, it might see the wisdom of becoming more compliant, and change its outlook to being a 'rule follower'. It may well then have the philosophy of '... just tell me what I have to do, and I'll do that ...'. The unspoken thought may be '... and that's all I'll be doing'. While the 'vulnerable' mine fails to recognise a hazard and cannot comprehend risk management, the 'rule follower' might accept a list of hazards from a regulator or a report, and conduct a (possibly perfunctory) risk assessment even if it's only to get an approval from the regulator.

Regulators would spend an inordinate amount of time with 'vulnerable' and 'rule follower' mines, generally with little satisfaction all round. Some perverse satisfaction may derive from a sense of power arising from the regulators' 'command and control'. If a mine is determined and survives being a 'rule follower' it is possible that it begrudgingly becomes

more organised. An approval infers that the body of knowledge resides with the regulator, that they (alone?) are aware of the factors to be addressed in all approvals, and that they make the necessary checks with others who have some expertise in parts of the process of the approval. It could be argued that the creators of risks should be able to do their own due diligence with the body of knowledge, and follow a proper process to arrive at the right answer relating to equipment use.

As the level of maturity increases, the regulatory environment should change. ‘Robust’ mines appreciate advice on broad obligations, and undertake good processes of risk assessment and risk management. A level of mutual respect evolves, with greater flexibility of performance. ‘Robust’ mines develop a safety improvement philosophy and practice, and see the value in developing a systematic approach to risk management generally. In a sense, the regulator must develop a belief in the mine’s capacity to make the correct decisions based on good information, and believe that they have good risk management practices pervading the workforce. It is also likely, especially in the case of ‘robust’ mines that some parts of the mine are struggling to evolve from ‘vulnerable’ or ‘rule follower’ status, while other parts are heading for ‘enlightened’ status.

‘Robust’ mines have a safety management plan. ‘Enlightened’ mines will take that plan and communicate it widely with all those involved in its implementation, including key stakeholders outside the mine. Those communications will be two-way in nature, having the effect of gaining the commitment of all for its successful implementation. As miners (and others) see how well their contributions are regarded, a level of trust should emerge. Regulators might participate in and contribute to the ‘enlightened’ mine’s communication of a safety improvement plan. Campaigns for sharing experiences of both ‘content’ and ‘process’ of these plans are likely to be seen across mines, with the active support/participation of regulators.

‘Enlightened’ mines will gain credibility within the local community, because communication skills within the community will benefit from the skills developed for internal application at the mine. ‘Enlightened’ mines will have the sort of communication channels whereby employees and key stakeholders feel that they can pass bad news up the line and have management deal properly with their information. In the case of ‘resilient’ mines this information travels informally, fast and is considered by all the right people, in the right way, because a level of trust has been established.

‘Resilient’ mines will constantly ask themselves if they’ve thought of all real risks, or how they might cope if a few risks converge. These mines are likely to be judged more for their duty of intent than their duty of care. Wider community support will be gained by these mines, who will probably experience a different intervention by regulators, aiming more at how different scenarios would be addressed, than with detail.

Communication evolution, for example, could be illustrated across the ‘maturity model’ in Table 6.3.1. This table builds on the work by K Weick (1985), P Hudson (2001), J Reason (1997) and P Sandman (1987) as well as the experience of the author.

Consultation has been a significant issue for regulators since Lord Robens’ Report (1972); see for example Working Paper 10, Workplace arrangements for OH&S in the 21st century, by Professor David Walters (2003). Flowing from this report, Australian occupational health and safety (OH&S) legislation enshrined OH&S committees as a way of mandating consultation and supporting communication. At the time of their introduction in the Australian mining industry, in the early 1980s, these committees were commonly

TABLE 6.3.1

Communication and its maturity evolution – showing typical communication maturity levels and corresponding regulatory responses – for consideration during project approval phases.

Common expressions of industry communications	
Vulnerable (or pathological)	• Hoard information – ‘tell ‘em nothing’ • ‘We do what we’re told and just get the job done’ • Focus on the technical – denial (and fear and blame) • Communication after the event – either defensively given or to allocate blame • Communication undeveloped – in the moment and unconsciously incompetent
Rule followers	• Information on a ‘need to know basis’ – ‘tell ‘em late and tell ‘em only what they must know’ • Information sharing within some groups and individuals • Do what’s in the rules/procedures – apathy • Communication as required by the law, not timely or caring for others – apart from certain peers/colleagues • Communication follows set procedures – day-to-day and rising awareness/becoming consciously incompetent
Robust	• ‘Tell ‘em heaps’ changing quickly to ... • ‘Let’s get it right the first time’ • Share information and consult – vertically and horizontally • ‘We plan what we do and we do what we say’ • Proper concern • Check steps in the task – do people know what to do? • Motivation through good communication • Communication strongly during risk assessment and analyses, as well as in decision making • Communication consistent with ‘we have a good culture around here’ – task focused and consciously competent
Enlightened	• ‘So, what are our options?’ – explore options, can handle objections • Negotiate properly – with better (not more) information, developing competencies and accountabilities – ‘what people think matters – feelings are as important as facts’ – and ‘has anyone any experience in this?’ • Effective two-way information exchange and across the organisation with guarded optimism • Monitors risks properly – do people know what to keep a look-out for, and how to respond? • Communication both professional judgement drawing on competencies/accountabilities – and timely, before the event • Communication consistent with a ‘trusting’ culture and outcome focused conscious competence
Resilient (or generative)	• ‘So, tell me something that would make me really uncomfortable’ • Delegate – (not hands-off but with constant interactive communication, monitoring and acceptance of accountabilities) • ‘Those we least want to talk to, we most need to talk to’ – build rapport because they understand people • ‘Openness is rewarding’ • Discussion over ‘what would happen if ...?’ – precautionary but not risk averse • Challenging for the good of all. Communication appropriate to the organisation’s values, and with stakeholder sensitivity • Communication unconsciously competent

TABLE 6.3.1 CONT ...

Typical regulatory responses	
Vulnerable (or pathological)	• Makes sure stakeholders have access to the rules • Let's them see a list of corrective actions required • Directives to set up a consultative committee • Works closely and confidentially with stakeholder representatives • Issues directions and stops work if uncertain
Rule followers	• Checks the operations of the consultation/liaison committee and encourages committee deliberations • Works more openly with stakeholder reps and checks access to guidelines/information • Challenges risk assessments to see that the right people have been involved • Is ready to reject applications that aren't fully justified • Needs to see comprehensive documentation and 'audits' level of knowledge and consultation processes • Begins to develop volumes of guidance material
Robust	• Checks that stakeholder/liaison committees are aware of risk management and systems implementation • Works more with risk management teams and leaders, and is more accepting of less documented justification, knowing the process is an informative one • Challenges context, scope, assumptions and extent of information • Actively supports wider information exchange • Supports management plans that aren't as detailed, but checks understanding (as opposed to audits of detailed knowledge) • Develops guidance regarding 'process' especially risk management processes
Enlightened	• Supports better (more meaningful if less, and interactive) information, considering options • Emphasises competencies and accountabilities • Challenges that individuals have not been forgotten in favour of groups and that expertise is being accessed, and accountabilities acknowledged • Checks public outrage factors and examination of options needing only limited documentation • Stresses development of maturing systematic management • 'What options do we have?' • Is anything missing?'
Resilient (or generative)	• Champions approaches from these sites • Looks for good things to convey across the industry • Supports industry's evolution of an 'expert system' of information • Focuses on what systematic management improvement issues have been implemented and discovered for improvement in near future • Checks emergency response plans, protocols and testing • Actively seeks out key threats and opportunities – to converge 'champions' and 'opportunities'

regarded as a waste of time or hindrance. While they initially forced a 'rule follower' approach, they began to be used for proper consultation and progressively evolved maturity. In this way it could be argued that these committees played a significant role in shifting organisations/sites from pathological/vulnerable to reactive/rule followers, and set the scene for some to go to the next level of maturity with teams conducting risk assessments, especially when statutory approvals mandated risk assessments. Risk

assessments require inclusive consultation and good guidance for the mining industry was produced on this topic in the 1990s and again in the early 2000s. Lately there has been added pressure from regulators on 'consultation'. This goes beyond OH&S, and is clearly required as part of risk assessments in project concept and EIS phases. Regulators would want evidence of meaningful communication and the participation of key people, through to those most exposed. A regulator would not be satisfied if simple (as opposed to meaningful) communication revealed that no one was concerned about the risk. Similarly, consultation and communication is increasingly seen by regulators as fundamental; *and as a 'show stopper'*.

Steps in evolving communication and consultation, relative to the above evolving 'maturity', include:

- understanding how an individual (ie independently) communicates and responds to communication – the roles and functions of the individuals involved
- understanding stakeholder expectations – how the individual or group is seen and needs to act – not just as an independent person but with some interdependency
- understanding team roles, functions and capabilities – where the sum of the team exceeds the sum of the individuals and where all have strengths and allowable weaknesses – addressing specific areas collectively
- using teams and individuals as circumstances suggest – to be comfortable/adept at exploring options – starting to integrate system elements for example, safety, environment, emergency, security, etc
- testing assumptions, encouraging initiative in a structured 'mental model' / 'collective mindfulness' culture.

The community will readily see the product of 'enlightened' and 'resilient' operations due to the impact on individuals and how this impact is manifested through consultation and communication. The industry could gain significantly in its acceptance in the community if it is seen as leading the way.

Property acquisition may be the toughest task as it requires the highest level of communication.

Consultation and communication processes utilise risk management. Converting risk management of separate items into an overarching systematic management of risks is demanded, even if few people understand what is involved or how to go about it. Communication is at the heart of this issue – 'who knows about our systems and do they really believe their contributions are well received?' When confronted with an issue, will they know what to do or will they make up their own mind; this is likely to result in a 'fight or flight' response – rather than a sound response, which is what the system would like them to do. 'Vulnerable' operations keep things secret, which is a very high-risk, virtually terminal strategy in this day and age. 'Rule follower' operations inform because they have to; they can inform late or they can tell the community what they want the community to hear, and this is less risky than keeping things secret. 'Robust' operations consult, and this is less risky again than 'rule followers', while 'enlightened' operations conduct effective negotiations, and 'resilient' operations delegate. These last two types of people can handle objections. They question and listen and enjoy exploring ideas though they have sound knowledge already, and can build rapport because they understand people, and they exude personal integrity (probably through the lessons of life, although a bit of forward planning and skill development can speed this up). Negotiating and delegating can result in progressively

higher risks, though this can be managed through the experiences gained while maturing to this level, and with a clear strategic direction, the development of strategic alliances and excellent communication skills.

RISK MANAGEMENT

Good communication follows the risk management process¹³, though the terms might be less formal. Initial risk assessment proceeds with hazard identification (issues and concerns), risk assessment (what are the biggest/priority concerns), risk controls (what are the options?), monitoring (tracking progress), testing and adjusting (modifying the plan in light of experience). Priorities will be determined and revised, and may include:

- balancing the needs of stakeholders and the organisation
- establishing a policy, protocol or procedure for a specific issue
- meeting specific objectives and modifying the plan as it unfolds
- measuring progress and performance, whether specifically or generally
- reporting specifically, as agreed or as required by conditions of approval
- complaints/feedback recording and response – a complaints/feedback register and response procedure is likely to prove advantageous
- reporting more generally or broadly, especially within the organisation or in the community
- reviewing and improving more generally or broadly.

POLICIES, PROTOCOLS AND PROCEDURES

These follow risk assessment. Typically, risk controls include policies, protocols and procedures. Some forms may be required to support these, and a records/information management system will be needed. These will all be needed prior to implementing the project, which is the third major step – implementation – which is addressed later.

RESPONSIBILITIES AND ACCOUNTABILITIES

These will flow from policies, protocols and procedures. They need to be explicit not implicit so it is clear who has to do what. They must be documented, probably in duty statements or the like, but don't need to be exhaustive; a few dot points should suffice.

TRAINING

It may be necessary for some training, in light of policies, protocols and procedures. People will be drawn from various backgrounds for the project approvals work and, while they may be experts in their own areas, they may not be sufficiently experienced in project approvals to implement policies, protocols or procedures.

RECORD KEEPING

All of the above – the major part of project approval planning, through to training – needs to be recorded, with document control, so the information is readily accessible.

13. Risk management is discussed as a separate topic in Chapter 10.5.

6.3.3 Statutory approvals

UNDERSTAND THE STAGES IN PROJECT APPROVALS – CONCEPT PLAN, ENVIRONMENTAL IMPACT STATEMENT AND LICENSES/AUTHORISATIONS/ APPROVALS

Assuming that the organisation has already obtained exploration rights and has the orebody reasonably well defined, the next step is to progress the feasibility of the project, as outlined in the previous sections of this chapter. This is to some extent iterative because it involves considering options that have differing financial implications.

Just as risk management progresses through hazard identification, risk assessment and risk control, statutory approvals should be thought of as progressing through the analogous stages of concept plans (to identify problems), the common EIS (that considers risk controls and monitoring, and take feedback into account) and issuing of licenses (which commonly prescribe risk controls and reporting). These stages require active listening and consideration of alternatives, necessitating the maturing of communicating skills. It also requires early discussion – not a ‘token risk assessment’ as the task begins. This starts with the collection of baseline data well before operations are expected to commence; and this will help give some indication of possible obstacles.

CONCEPT PLAN – CONSULT AND TRULY LISTEN

When preparation has reached a stage of comfort in accommodating criticism, start to consult properly, and with those most likely to support the project. The results of the consultation are progressively formalised. The more comfortable the project proponents are with taking on board any criticism, the earlier consultation begins – just don’t rush in where angels fear to tread – and make sure project objectives are clear, because negotiations will involve everyone, and will tackle a wide range of views.

Keep all impacts on site and be empathetic to others who will be affected.

The concept plan will have identified:

- *Site issues* – surrounding land use, local culture and politics, floods, emergency services, visual and cumulative impacts, energy demands and some options possibly involving easements, treatment works and tailings dams, ventilation facilities for underground deposits, sterilisation drilling for key facilities (such as the mill).
- *Employment opportunities and impacts* – understand that providing well-paid jobs will not please local businesses if the operation pays well above the local level and attracts all the talent out of the community. Accommodation needs may have to be dramatically increased; fly-in, fly-out arrangements may not be sustainable, nor appreciated by local businesses or within the community. Accommodation during the construction phase will probably be very tight, so anticipate initial transitory employee impacts as well as ongoing impacts.
- *Typical environmental issues and concerns* – transport impacts, dust, noise, air quality, community impacts, dangerous goods and facilities, 24-hour operational impacts.
- *Infrastructure needs* – roads and road access changes, railways, transport facilities (such as stockpiles and reclaim facilities, rail sidings, ports), communications, water supply, sewerage.

Formalising of the concept plan progresses with input from those involved in concept plan considerations. At the beginning it is relatively informal and will become formal.

Most mines, other than small-scale artisanal mining, require formal plans to be submitted for approval. There is sometimes a ‘threshold’ level of proximity to residential areas that might permit a more local level of approval, but this is commonly qualified by location to coastal or sensitive areas, geological, slope or soil conditions and other mining and extractive industry operations – the cumulative impact condition.

The more sensitive, cumulative impact or the larger the scale of the project the more likely it is to move from local government to state and Commonwealth-level approval. While the Commonwealth Government does not have to give a mining title approval, it generally retains the ability to block a project by refusing an export license – often of critical importance in the mining industry. After obtaining geological information from the Commonwealth, they are often the last to be consulted. State and Commonwealth governments collect, compile and analyse geological data. Unless the Australian Constitution is changed, mineral rights are state responsibilities, so mining titles, if they are required, will be issued by them. Mining titles are usually *mineral specific*. This means that even if the *specified mineral rights* and the land are owned by the title holder this will be relevant in a dispute if another organisation wishes to search for a mineral not listed in the title.

State governments are generally the best place to start consulting. Their level of interest, local knowledge, experience in project approvals and their support will be very helpful and constructive – if something has been missed, they are likely to help find it. Remember that their objectives include sustainability, stewardship of the resource, sound operational and extraction practices, optimising returns to the state, employment, care for the environment, local infrastructure and development and good corporate citizenship. Their objectives, while differently expressed, should be compatible with those of the project. Even so, negotiations may be involved.

Make an appointment early with the most relevant state government agency concerned with geological data – to discuss a mine concept plan. The early appointment is necessary so that a group from different parts of the agency can come together with something to add, having gained some local knowledge. The concept plan is going to be refined, and this might involve referrals to other government agencies for particular input. If this happens it is likely to be a priority issue due to the issue’s significance from a statutory approvals perspective.

The technology of a mining project is one thing, but equally important are ‘culture’ and ‘politics’, so the level of consultation and communicating are generally critical to approvals being given. There are invariably options in achieving ‘how’ the project proceeds. It is, of course, vital to communicate what is legally required, but it is far better to be inclusive. Better still is to be comfortable in considering options, but this has a level of risk, depending on the level of maturity of those included. Better again, but more risky and heavily dependent on the level of maturity of those included, is the invitation to openly discuss and respond to any concern.

The concept plan will be evolving towards the next stage, namely an environmental impact statement (EIS) in which all the impacts (hazards) of the project will be identified. The respective (risk) controls and monitoring will also have been examined.

It would be wise to consider processes of reviewing, reporting and improvement consultation mechanisms, which will be the focus of the third stage, namely the ‘licenses’ themselves. It is unlikely that they will have much influence over license conditions, but the only way of influencing them is to have some management processes in mind. Failure to do so will probably result in more prescription in the conditions than is warranted; meaning that

prescriptive requirements will last for the life of the project, as opposed to having broader objectives or outcomes to achieve and more flexibility in the ways of achieving them.

TAKE A BULK SAMPLE IF ALLOWED

The regulator who will issue a mining title is probably the one to approach for approval to take a bulk sample. This might be possible under an exploration/prospecting title. Apart from the more obvious technical reasons, a bulk sample can help identify suitable extraction and treatment processing requirements, possible contamination as well as suitable means of containing all pollution, with contingencies.

ENGAGE RELEVANT REGULATORS AS A GROUP (PLANNING FOCUS)

As soon as the project is ready to go beyond the concept plan stage, ask or encourage a government agency (typically the one that will issue the mining title or the 'Development/Investment' agency) to invite senior representatives of the relevant regulators to a meeting to consider the project. This allows all regulators to appreciate other views and allows some collective agreement; these are important. By this stage all authorisations likely to be required will have been identified and work can proceed with a bit more certainty on respective documents to support your applications for specific licenses. Licenses or approvals involved in the project may include the following.

Water management

Water availability and use will invariably be a major issue. Water and environment protection legislation commonly applies, and is likely to require a license for storage above relatively modest quantities. Extraction of water from bores and watercourses is also likely to attract a license approval. Water harvesting on site is becoming a more widespread requirement to the extent that discharges off-site may be limited to unseasonal rain events. The quality of any water leaving the site may have to be better than water coming or harvested on site.

Water is often a very vexed issue in the community, with competing needs, so a high level of consultation and control is required. A water management plan may be required, necessitating collection of meteorological data, water balance modelling, probability of system over-capacity or of insufficiency, and possible flood intensity. The Commonwealth's Department of Sustainability, Environment, Water, Population and Communities' (Environment Australia) Best Practice Environmental Management (BPEM) guide on water management might be useful.

Air quality

Environmental and National Pollutant Inventory obligations commonly apply. Dust hazards, risks and controls, as well as monitoring and reporting approaches are needed. Dust management is described well in Environment Australia's BPEM guide on 'dust control'.

The National Pollutant Inventory (NPI) has been developed as a National Environment Protection Measure by a consortium of Commonwealth and state governments. At this stage reporting on 36 substances is obligatory (if triggered), and mandatory reporting of 90 substances (if triggered) commenced on 1 July 2001. Full details can be obtained from – National Pollutant Inventory Guide Emission Estimation Technique Manual for Mining and Processing of Non-Metallic Minerals (Commonwealth of Australia, 2012).

All sites that meet any of the following criteria will have to report all designated emissions:

- burns more than 400 t of fuel or waste a year
- burns one tonne or more of fuel or waste in any one hour
- consumes more than 60 000 MW or more a year or has a maximum potential power consumption at any one time of 20 MW or more.

There are other reporting triggers, eg when the level of arsenic or lead in the dust emissions is such that greater than 10 t/a of lead or arsenic are emitted. Expert help in determining the substances' emitted level of emission and reporting requirements is recommended.

Environment Australia considers explosives to be a fuel. This means that all sites that detonate more than one tonne of explosive at once (in the one blast), fall under the NPI reporting requirements, regardless of other trigger mechanisms.

Under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC), if states do not have a bilateral agreement with the Commonwealth, any project having a significant impact on a matter of national environmental significance must be referred to the Minister for the Environment.

Noise, air blast over-pressure and vibration

Environmental obligations commonly apply. 'Sound' and 'ground vibration' licences are likely to be required, especially if there is any blasting involved. Good guidance is available in the BPEM on 'noise, vibration and air blast control'.

Earthworks, rehabilitation and soil conservation

Approval conditions are likely to require an environmental management plan that has earthworks for rehabilitation as a central issue. Helping 'mother nature' with a good landform will help you. A substantial (financial) bond will be set in relation to this, and progressive rehabilitation will be expected, with annual reports being common.

Flora, fauna and biodiversity

National parks, threatened species and native vegetation legislation commonly applies, commonly identifying locally significant flora, fauna and biodiversity features, and threatened and endangered species obligations.

Heritage, cultural and Aboriginal recognition

Local, regional and national Aboriginal Lands Councils might all be involved. It should not be assumed that they will share common interests; it is recommended that specialist advice be sought in relation to consultation and communication with each body. The consultation may not go according to the planned timing, location or manner; adaptability is the key.

Determine the required steps in the event that any Aboriginal site is discovered during mining; eg who, what, when it should or must be left undisturbed and reported to the appropriate agency, commonly a state-based national parks and wildlife agency or other interested party.

Native Title is addressed in a later paragraph.

Dangerous goods and major hazard facilities

Dangerous goods, hazardous substances, major hazard facilities legislation commonly applies. Dangerous goods legislation might cover explosives legislation, which could impose additional requirements.

In the case of explosives, Australian and New Zealand Standard 2187 contains additional information. An explosives and blasting management plan is likely to be required.

Licenses may be required for storage, handling and transport of dangerous goods/hazardous substances. The mining industry almost always exceeds threshold levels, which triggers these requirements as necessary.

Transport

Transport of mine products by road, rail or other¹⁴, will need to be considered, with relevant discussions held early. Truck movements commonly cause community concern, but rail transport might also prove challenging with rail loops/sidings and associated load-out facilities, freight scheduling, unloading and rail infrastructure upgrades.

Truck access to local roads can be directed to certain places and at times that don't conflict with school bus times for example.

Road intersections and fly-over bridges/interchanges might be required as part of an operating license, even if it is included on behalf of another agency (local, state or Commonwealth).

Transport by workers to and from the site might also be considered, especially if upgrades to airstrips are required.

Transport on site can even be required to control reversing warnings where these may be an unwanted noise at nights.

Subsidence or ground movement

Whether or not subsidence or ground movement is expected, any infrastructure that might be impacted by unplanned ground movement must be identified and considered. Even underground drives that cross under railways will need to be discussed and approvals are likely to contain limiting conditions. These approvals may be given as part of a lease/tenement condition rather than by a rail authority for example. Further, underground openings might trigger movement in minor faults that are being monitored by road authorities, even where they are not directly underneath the bridge or roadway of interest.

Visual amenity

Visual impacts of the mine must be considered as significant, for these may be a constant irritation to any opponent of the project and cause frequent complaint, some of which will be hard to overcome at the time due to fluid political conditions. Visual amenity is likely to be part of any license to operate, even if indirectly.

Waste management

Waste minimisation and environment protection legislation commonly applies, involving licenses for waste disposal occurring on site. The generation, storage and transport off-site of certain wastes (such as waste grease, oil and solvents) may place additional requirements on the site. Advice should be sought from the respective environmental protection agency.

Community and socio-economic impacts

Community consultation is almost always required, and this is paramount at local government levels, but is also very high on the agenda for state and Commonwealth

14. Transport of radioactive product matter is a special case. Readers are referred to the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) codes of practice, referred to as the Radiation Protection Series (see <http://www.arpansa.gov.au>).

agencies. Volumes are written about community and socio-economic impacts, so take the time to consider these.

The key is to look at these impacts from the community's perspective not just that the mine will create jobs and help local business. Some, generally smaller, communities may not welcome a mine that pays high wages that attract the more capable people away from existing businesses.

Safety management and major hazard management plans

Mine safety legislation commonly requires safe systems of work and major hazard plans for such hazards as explosives and ground control, especially near lease boundaries.

Energy use, efficiency and greenhouse impacts

More and more pressure is being placed on energy use, recycling and greenhouse impacts. Even if there are no limits or targets placed on the project by government agencies, their support may be conditional on the site having a management plan for these issues.

Decommissioning

Plan this as early as possible and take progressive action wherever possible; start the earth screening and plant screening early for example. People may be more likely to accept a hole in the ground than a rubbish pit at the end of mine life.¹⁵ If there is likely to be any ongoing acid mine drainage, measures to ameliorate it will be required.

Other extractive industries in the area might find the void useful, so it is worth examining this possibility as well.

Decommissioning can also create community stress by the loss of jobs and flow-on impacts, suggesting that this human dimension be considered before community consultation begins.

Environmental monitoring and reports

Environmental monitoring and reporting is essential, both to track the site's own performance and to report publicly, which is generally required. Monitoring will include the site's implementation of an environmental management plan as well as any requirements arising from approvals. Even if the reports are not made public, assume they will be 'discovered'; so the best course, generally, is to be proactive rather than acting from a defensive position.

Security

A security plan is likely to be required as part of an explosives storage license or, if large quantities are not stored but are brought on site by a supplier. This could even be a requirement for any blasting while taking a bulk sample. Security arrangements will include the following (minimal) requirements:

- Licensee information.
- Security risks and controls.
- Sketch/plan of site, with details of all facilities and boundaries.
- Extra lighting or the use of closed circuit television (CCTV) and recording information required following the risk assessment (these controls are site dependent).

15. Consultation with the local shire council might reveal a need for additional landfill.

- List of people with unsupervised access to explosives (list of nominated persons holding security checks and shotfiring ‘tickets’). Access to the compound and/or magazine must only be by authorised personnel or in the company of authorised personnel only.
- Description of the secure store/magazine.
- Key security and register location/maintenance. A sign-in/out procedure must exist for the allocation of keys. The keys to the magazine and compound must also be kept locked and secured. These keys must be kept in a separate location to the general storage of keys for other purposes. An audit of the sign-in/out procedure must be conducted monthly and the results registered with the site manager.
- Details of training.
- Details of stock in and out.
- Transport details.
- Other security information required by relevant government agencies, eg access to gates by the State Emergency Service (SES), fire brigades, etc.

Contact details for personnel responsible in the event of a breach of security, theft or missing explosives should be kept with the register of authorised personnel and in the emergency response plan.

Emergency response

Emergencies also need to cover natural disasters as well as covering any explosives usage. Communication is the key while the project is gaining approval and satellite phones might be required. Satellite global positioning system (GPS) coordinates should be determined at the outset of work on the project.

Emergency preparedness and response (with an emphasis on explosives) encompasses:

- The equipment and facilities that will be available to optimise the site’s ability to respond promptly and minimise damage or potential for loss of life.
- The procedures that will be followed and the measures that will be taken, including matters such as maintenance and checks, sounding alarms and evacuating people.
- Fires will be fought to prevent them spreading to explosives but fires involving explosives will generally not be fought, and will necessitate evacuation to a reasonable distance (normally at least 500 m) and sentries posted.
- Training, drills and exercises in those procedures.
- The measures that will be taken to investigate why the incident or situation occurred.
- The individuals who will be responsible for implementing the emergency management plan (EMP).
- The measures that will be taken to train people to execute the EMP.
- Which emergency services and other people will be given a copy of the EMP. Emergency services such as fire fighters, police and other responders that may be included in the EMP will be consulted in its development and will have access to the latest version of the plan. Neighbours or persons/organisations that could be affected should an incident or dangerous situation occur should be provided with a copy.

All shotfirers have a responsibility to keep the EMP up-to-date, with approvals by the site manager. Shotfirers will constantly check emergency procedures for possible eventualities, including:

- fire
- mixing or manufacturing problems
- transport accidents
- natural phenomena such as lightning, strong wind, dust storms, flooding, major ground movement
- electrical hazards
- unplanned detonation / premature initiation
- unauthorised site entry
- deteriorated explosives
- injury to people / harm to property
- damage to the environment
- theft/unexplained loss of explosives
- flyrock.

CONDITIONS OF APPROVAL

Conditions of approval can be prescriptive, or process, performance, or outcome-based. The most flexible are outcome based but this might not suit opponents of the project, so try to limit these by proactive consideration.

Conditions will need to be monitored, audited and reviewed as well as reported at regular times.

6.3.4 Shire approvals

LOCAL AND STATE SIGNIFICANT PROJECTS

Development consent is commonly required for larger-scale operations or where there is a cumulative impact created by a number of smaller operations. It is generally best to engage local government first, and to leave the development consent in their hands. This will develop local support for the project. However, this is not always possible, especially in the case of state-significant projects or when local opposition appears intractable.

COMMUNITY OUTRAGE

Community outrage, as addressed well by Dr Peter Sandman (1987), can be hard to control. A feel for community outrage might be gleaned from local government and from local representatives of government agencies. A site culture should be determined from the outset. A 'them and us' culture is unlikely to succeed, while a rule-following culture will not be attractive. A robust culture that encourages inclusive processes will be obvious and start to attract support, while a more enlightened culture, with its level of comfort in dealing with options will appear far more attractive. In an enlightened culture, 'the people you least wish to talk to are probably the ones you most need to talk to', but opposition to mining is not always logical, so it might be necessary to communicate with uninvolved neutrals. Consider the debate about coal seam gas extraction, and the way that opponents have engaged people who are unlikely ever to be affected, and the political reaction to the concerns of those people. Again, preparation is the key. Prepare for a community meeting with good information, clear objectives, an ability to dodge personal insults, an affinity for 'islands of agreement' and adaptability to consider options about how to achieve everyone's objectives – backed up by commitment to achieve any and all agreements made.

LOCATION AND GEOGRAPHICAL SITUATION INCLUDING DRAINAGE

Aspects of the project's geography, especially those that will impact on others, such as water collection and drainage, will need to be considered from the beginning.

INFRASTRUCTURE AND UTILITIES

Local government will be interested in any infrastructure or utility of value to the community, including the obvious, such as roads, as well as the less obvious, such as schools, libraries, parks, bridges and the like. Access to power may also be negotiated at a regional level.

SURROUNDING LAND USE

The project has to consider the surrounding land use and any impacts on those. This is not always incompatible; grazing or cropping can still continue on lands encompassed but not used by the project.

LIGHTING

If the project will operate at all hours of the day, and lighting is installed, it will need to be unobtrusive and located to avoid intrusion.

LABOUR MARKET AND SOCIO-ECONOMIC IMPACTS WITHIN THE COMMUNITY

While mining can bring employment into a community that could benefit by those opportunities, the test you might like to consider is 'would you want to work here?' A site culture can be imposed on the basic geology and geography parameters and this could set about influencing employee commitment to the same test.

VISUAL EXPOSURE AND ENHANCING THE LOCAL ENVIRONMENT

Visual amenity has already been mentioned. If there are ways of improving the visual amenity, even by providing viewing platforms and supporting local tourism, this might help with local support.

PROGRESSIVE LAND REHABILITATION AND CHANGE OF LAND USE

Progressively rehabilitating the property is a necessity, and this will need to a land use other than it had been before mining. Local government will have any number of ideas. Obvious ones are not always welcomed enthusiastically; local governments often desire something quite different to attract outside interest and tourism.

WASTE MANAGEMENT, RECYCLING AND SUSTAINABILITY

There may be pressure, supported by local government pressure, to leave the site for future land use as a tip/dump. If that is what the community wants, then such a plan may well be accommodated. However, it might not be accepted by the community at large, especially if the waste comes from outside the local community.

BUILDING APPROVALS AND CONTRIBUTIONS

In addition to local government consent to the project, and after the project commences, building approval may be required. This is not always given as a matter of course; it might trigger further pressure for local government contributions, such as for sealing of the road to the mine even where other contributions have already been given. Arguments are not always factual either; for example, the local building code might not suit mining conditions, where, for example, marine grade galvanising might be required for mill buildings.

FINAL REVIEW AND LEARNING

At all times a good relationship at local government level is required, regardless of where the development consent/approval is given. This needs to be consolidated at the end of the approvals processes, because an extension might one day be sought, and because the industry needs to maintain a good reputation for sustainability and 'license to operate' reasons. Local government will be invited to the opening ceremony and they need to be recognised. Like all tiers of government, they are surprise and criticism averse, so conduct a good debrief. More mention is made of this in section 6.3.10.

6.3.5 Native title approvals

NATIVE TITLE CONSIDERATION

Native title consideration can commence at a local level but it might not stop there. Native title is the recognition by Australian law that some Indigenous people have rights and interests to their land that come from their traditional laws and customs.

The native title rights and interests held by particular Indigenous people will depend on both their traditional laws and customs and what interests are held by others in the area concerned. Generally speaking, native title must give way to the rights held by others. The capacity of Australian law to recognise the rights and interests held under traditional law and custom will also be a factor.

Native title rights and interests may include rights to:

- live on the area
- access the area for traditional purposes, like camping or to undertake ceremonies
- visit and protect important places and sites
- hunt, fish and gather food or traditional resources like water, wood and ochre
- teach law and custom on country.

In some cases, native title includes the right to possess and occupy an area to the exclusion of all others (often called 'exclusive possession'). This includes the right to control access to, and use of, the area concerned. However, this right can only be recognised over certain parts of Australia, such as unallocated or vacant Crown land and some areas already held by, or for, Indigenous Australians.

Native title rights and interests differ from Indigenous land rights in that the source of land rights is a grant of title from government. The source of native title rights and interests is the system of traditional laws and customs of the native title holders themselves.

Native title approvals commonly require an agreement. These can be complex, involving a different culture, so a different way of thinking is generally essential.

MINING AGREEMENTS

Advice on mining agreements with traditional owners can be obtained from the internet¹⁶.

In such mining agreements, key objectives to keep in mind are:

- parties need to be committed to the agreement
- if developing an ongoing relationship between the parties then a communication strategy needs to be set, including

16. For example, see <http://www.nntt.gov.au/mediation-and-agreement-making-services/documents/mining%20agreements%20content%20ideas.pdf>

- face-to-face meetings
- out of session communication (email, telephone, written, etc, with their difficulties)
- respect and goodwill
- mutual acknowledgement of rights
- the terms, legal procedures and time frames need to be understood by the parties throughout the agreement
- the parties need to be kept informed of achievements, milestones and the alternatives
- a means to ensure to the greatest extent possible that ‘outcomes promised in agreements actually materialise’
- preferably achievement focused
- an implementation plan/schedule needs to be set that specifies who is responsible for what actions and when
- the plan may also include provisions for resourcing the implementation of the agreement – immediate support post-agreement and longer-term support to build stability
- specific provisions for monitoring, review (periodic and regular), management and liaison may be agreed to if appropriate for the agreement.

INDIGENOUS LAND USE AGREEMENTS

An indigenous land use agreement (ILUA) may be a good start even if going on to the National Native Title Tribunal. It is a statutory agreement about the use and management of land that can be made between a native title party and other interested parties such as state governments. ILUAs allow people to negotiate flexible, pragmatic agreements to suit their particular circumstances. While ILUAs can be made separately from the formal native title process, they may also be stepping-stones towards, or be part of, native title determinations. An ILUA may have been part of the granting of an exploration/prospecting licence. A decision about whether to use an indigenous land use agreement needs to be made on a case-by-case basis and readers should refer to other tribunal guides to assist them in this decision¹⁷. ILUAs may be made about matters such as:

- native title holders agreeing to future developments
- the relationship between native title rights and the rights of other people
- access and/or management arrangements
- surrender of native title
- compensation.

AGREEMENTS IN RESPONSE TO A SECTION 29 NOTICE

To validly undertake an act that attracts the right to negotiate, a government has two options. It can either negotiate an indigenous land use agreement (ILUA) with the native title holders and carry out the act in the manner allowed by that ILUA, or it must comply with the ‘right to negotiate’ procedures set out in Subdivision P of the *Native Title Act 1993*. Section 29 of the *Native Title Act 1993* requires that before the commencement of a future act under Subdivision P, the relevant government must give notice to native title parties and the public.

Section 29 notices are issued by governments where it is intended, in certain circumstances, to grant mining tenements or where it is intended to compulsorily acquire land or expedite the negotiation and granting procedure. Under Part 2, Division 3 of the *Native Title Act 1993*,

17. See: <http://www.nntt.gov.au/indigenous-land-use-agreements/procedures-and-guidelines/documents/short%20guide%20to%20registration.pdf>

registered native title claimants and registered native title bodies corporate (native title parties) are entitled to special procedural rights in relation to acts to which Subdivision P applies – namely the grant of certain mining tenements and certain compulsory acquisitions of native title rights and interests. This package of procedural rights is called the ‘right to negotiate’. One of the fundamental principles of the right to negotiate is that any relevant act will be invalid to the extent that it affects native title unless it is done in accordance with the procedures set out in the *Native Title Act 1993*.

6.3.6 Landowner agreements

CONSULTATION AND COMMUNICATION

Landowners need to be able to express any concerns about the project and be included in a mutually agreed solution. One of the classical issues is access, and the general principal is to start with the shortest but most practical route to a public road. Another will be access to water or water harvesting. Dust onto feed in adjacent pastures can be an issue if it stops livestock grazing. Compensation might be sought but some works in exchange might be preferable. When issues and concerns are raised, suitable controls will be necessary, and if the communication is relatively mature, options could be identified.

It might be prudent to give a good communicator the task of consultation and communication, but the opportunity should not be missed to develop these skills, through practise. That might involve the support of the good communicator, even if that person sits beside the project manager and gives support at critical times during the discussion.

MEETING COMMON OBJECTIVES, TIMING AND COST

Strong neighbourly relations will ease the approvals process as well as in the longer term. Landowners will have their own objectives, timing, costs and needs, including information needs. Their objectives may well not be aligned with that of the project proponent. Reaching agreement about how the project impacts on them in the least intrusive way is vital. Planning what is done and doing what is planned, and communicating often, is vital to instill trust. This is an absolute necessity where the landowner has influence in the local community.

COMMUNITY CONSULTATION

There are many volumes devoted to community relations and this indicates how important it is to get the community on-side, or at least not off-side. The ability to consider options should be prized; it is often uncomfortable opening up dialogue because this has an element of risk about it. It takes effort to develop this level of comfort, but like all skills, a bit of practice is rewarding.

If consultation or communication breaks down or is evidently going to be difficult, a bit of professional negotiation help would be wise – not to do the consultation or communication but to help key project personnel develop the skills. As with all negotiation, most of the effort goes into the preparation – time, place and manner of the actual negotiation – but don’t ignore the importance of good follow-through.

FEEDBACK

Confirming that actions as agreed have reached a certain milestone or have been completed is essential in establishing trust. Many mines also see great value in open days, but there are other ways of getting information about the operation back into the community.

6.3.7 Management of the approvals process

OBJECTIVES

Again, it is more important to keep project objectives in mind and be more flexible about *how* these are achieved. Options should always be discussed and ‘islands of agreement’ between parties always kept to the fore. While there might be clearly better ways of doing something, it might achieve a better lasting result to be accommodating of another view.

APPROVALS PROCESS PLAN

The key to gaining approvals with least difficulty is in the preparation. The whole approvals journey needs to be mapped, recognising likely or even possible obstacles and examining alternative ways of overcoming them. Think of the obstacles from the other party’s perspective and even consider possible deadlock breaking options. Examine all available information then proceed with consultation and communication.

MANAGEMENT PLANS FOR MAJOR HAZARDS

Some of the obstacles will be so significant that a management plan should be considered at the outset. This is likely to yield a better result than having a prescriptive condition of approval. Management plans need thought and effort, but they are more flexible and more widely acceptable. Set a common structure for system elements and for management plans so they are more readily integrated.

INFORMATION MANAGEMENT

A wealth of information about the project will be compiled. A document control system for information and knowledge management (I&KM)¹⁸ may well be of use. This will establish distribution control if it provides guidance and/or direction for performing work, making decisions and retaining ‘corporate memory’, so:

- establish a system to identify, record, distribute and retrieve documents
- make sure current documents, records and information are easily accessible, distributed and kept for the required time
- include all documents, records and information, specifically related to the overall system and all subsystems, for example the health and safety system
- consult all employees and contractors, who are encouraged to provide feedback into the document control process
- assess risks, including that incorrect documents are retrieved or correct ones are unretrievable, or if incorrect information is provided, which may lead to a poor decision or an incident
- issue and keep documents, records and information in accordance with documented procedures, which need to be monitored and adjusted.

The I&KM system for a project must clearly define what data will be collected and by what methods. It must outline how data will be analysed to generate the information needed by different stakeholders. The cost, effort and time spent in collecting and analysing data must be balanced against the relevance and importance of the information that can be generated from analysing the data. To maximise the usefulness of information, project I&KM systems should be linked to a broader program or organisation-level information framework where possible.

18. A search engine will yield considerable reference material on this topic for interested readers.

RESPONSIBILITIES AND ACCOUNTABILITIES

Any system requires identification of responsibilities and accountabilities. These should be identified as broadly as possible and be compatible with the project management organisational structure. If these show any need for personnel development, training in critical areas might be essential.

TRAINING AND WORKFORCE DEVELOPMENT

Training and awareness in system elements is the key to good responses in times of need. This provides a structured mind and helps a focus on objectives. Objectives of training include securing the commitment of employees and contractors to the site's obligations stemming from approvals and commitments. This might involve awareness, skills enhancement or development, refreshment and, in some cases, formal skills competency training and assessment. Training in project and contractor management, negotiations and even team roles might be useful.

RECORDS

Records should be kept right from commencement, and some of these will be accessed many times. A site plan should be developed for use in multiple ways – everything from site description, inductions, security, licence application attachments, blast exclusion zones, to emergency response, etc.

A formal approval to commence might be required. This could be in relation to specific building approvals to notification of the local mines inspector.

Records must be kept of all of these approvals and notifications.

6.3.8 Implementing after the approvals process

PRECONTRACT PHASE

Contractors will certainly be engaged so establish a contractor management plan. Time and resources are frequently allocated in proportion to the size and type of the contract. For example 'major' and 'medium' contracts usually involve formal contractual documentation and the processes of work are detailed and thorough, whilst 'minor' contracts and 'casual' contracts are generally less controlled, with detailed documentation and documented procedures and processes less prevalent.

As a general policy, sites will anticipate engaging contractors and build their system and plan to accommodate contractors. Contractors will often have their own system, policy, procedures and relevant documentation ready at hand. Risk assessments, procedures and other relevant documentation will be developed by the site and also be ready at hand. Contractors have a right to access relevant parts of the site's system documentation and sites will need to see and verify contractors' documentation. Sites are likely to benefit from accommodating contractors' system elements within the site's system.

An open, planned and consultative approach is the best course. Both parties need to satisfy themselves of what is going to be done, who holds key accountabilities, how progress will be checked and adjusted, and how long-term improvements will be decided and implemented. At least in respect of major and medium contracts, certain documents, such as risk assessments, a scope of work and safe work method statements, will be commonplace.

Labour hire organisations should not assume that they have little or no responsibility for the people they place at mines. Quite the contrary, these organisations should assume they have due diligence and duty of care obligations.

Access to the site will be controlled and inductions (from informal through formal to comprehensive) will be carried out relative to the level of risk.

Work will be coordinated, accountabilities understood and valued, and adjustments to planned work made consultatively. Competency of contractor employees needs to be verified, and vital concerns must be managed properly.

Progress will be monitored regularly. For contracts that last some time regular reports will help communication and will help review risk controls to move them as high up the hierarchy of risk controls as is reasonable; this should help both parties.

Contracts will often have a review process at the end of or at least every 12 months during the contract; at the very least to examine what went well and what could be improved for next time. Sites should determine at these reviews whether or not to put the contractor on a 'preferred contractor' list, and the contractor should be made aware of this decision. The contractor may be invited to offer suggestions for improving the site's system. Site and contractor documentation may need improving accordingly.

Documentation must never be compiled for its own sake. The volume of documentation generally increases with the level of maturity of systematic management up to a point at which it decreases – at about the 'robust' level, when the need is for better information, not more of it. At the point of decreasing the volume of documentation, sites and contractors will have become more disciplined in their approaches and accountabilities and competencies will have been more valued. Communication at this point will also have become more effective and meaningful.

ENGAGEMENT OF CONTRACTORS

Effective contract relationships are built on key principles:

- both parties have equal obligations for proper due diligence and the exercise of duty of care
- clear and common objectives for both parties, who aim to minimise harm to anyone or anything
- sharing common objectives of both parties ('best for project' and cooperatively negotiating the key obstacles to reaching those shared objective) helps the process of both parties reach a mutual understanding
- both parties have an obligation to initiate open and regular consultation and communication
- both parties benefit from understanding and accepting a high level of accountabilities – without blame
- preparation and planning are key to good performance – 'plan what you do and do what you say' is a good message to broadcast and live up to
- adopting a long-term (or life cycle) approach – from initial preparation, through joint conferring, on-site management to debriefing after the task has been completed – benefits both parties
- being open to new ideas and regarding challenges as opportunities for personal development – knowledge, skills, experience and personal accountability – are highly valued by both parties

- formalising arrangements aids consultation and communication, rather than documentation done primarily for defensive reasons.

The sharing of responsibilities is likely to be enhanced by arrangements that express the obligations of the partners. These expressions become more important as the level of risk increases. Explicit, rather than implicit, responsibilities might address:

- outlining the objectives of both parties
- identifying business risks and rewards that do not have the affect of individuals being tempted to take short cuts
- creating a joint project management team
- a tender process that looks at OH&S management before examining costs/pricing
- both parties formalising regular communication and review processes.

CONSTRUCTION AND MANAGEMENT OF CONTRACTS

Case law indicates that courts expect employers to extend a high standard of care to contractors and that employers cannot simply rely on contractors themselves to implement safe work practices. In particular, the law requires mine owners and operators to take a similar degree of care for the health and safety of their contractors as they do for their own employees, particularly where the principal has control over the work area in which the contractor is working.

In order to ensure legal requirements are satisfied it is vital that mine operators and principals in their dealings with all contractors:

- assume a standard of reasonable care
- are able to demonstrate that due diligence was applied to the processes for selecting and managing the performance of contractors
- document their OH&S decision-making process, audits and follow-ups
- take account of their obligation when entering into a contract to ensure they have the power to
 - impose appropriate safety standards
 - refuse entry to any contractor who does not cooperate
 - terminate a contract where the severity or frequency of non-compliance demands such action.

OPENING CELEBRATIONS

Consider an appropriate opening ceremony or ceremonies at or near the end of the construction phase; more than one if necessary.

6.3.9 Monitoring and reporting in accordance with approvals

KEY PERFORMANCE INDICATORS

Key performance indicators (KPIs) should have been identified during the early planning phases. The classic KPIs include 'on time', 'within budget' and 'as per plan' and these will be supplemented by KPIs relating to the anticipated obstacles. However, approvals also may have explicitly or implicitly required measurement of progress in areas of particular interest. KPIs include positive (eg 'as per plan', etc) as well as negative indicators, such as unexpected obstacles or non-compliances.

It is also accepted mining practice to produce operations reports on a monthly basis, but for largely internal consumption.

REPORTING/NOTIFICATIONS

KPIs must be reported regularly, meaning monthly for the approvals phase.

In a number of cases an explanation is also needed. Explanations can be as simple as four questions:

1. What happened?
2. What was the reaction to the issue/concern?
3. Who is doing what right now to address the issue/concern?
4. What is the next milestone to be reached in addressing the issue/concern (what and when)?

CONSULTATION MECHANISMS

Consultation mechanisms, involving meetings of representatives of interested parties are often a good way of dealing with both the positive and negative KPIs. They should be anticipated early, and used to manage through the successes and the challenges. If they are seen as a way of addressing both, it will be easier to keep the ‘islands of agreement’ in sight, and keep the channels of communication open. They will also be useful for the establishment, implementation and maintenance of management plans.

6.3.10 Improving the approvals process for next time

IMPROVEMENT CONSULTATION MECHANISMS/PROCESSES

At the end of the project approvals phase, and with the benefit of the routine consultation mechanisms or processes, a special meeting may be wise to consider:

- What did the project set out to achieve?
- How did we go about that?
- What serious obstacles did we confront, and how did we address these?
- What went really well?
- What do we need to do better next time?
- So how should we upgrade our project approvals system, and who is going to do what by when to improve it for next time?

COMMUNICATE SUCCESS AND IMPROVEMENTS MADE

Once the improvement has been made the following should be considered: ‘Who needs to know how we’ve done, what went really well, and what we’re going to improve for next time?’ This might form part of the opening address by the organisation.

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The AusIMM Project Evaluation Conference Proceedings series (2007, 2009, 2012) contain many papers on a wide variety of topics relating to project evaluation. All papers from these conferences are available on The AusIMM online shop (<http://www.ausimm.com/shop>).

CHAPTER 7

OPERATIONS MANAGEMENT

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MMG is a mid-tier global resources company that explores, develops and mines base metal projects around the world. MMG is headquartered in Melbourne, Australia and is listed on the Hong Kong Stock Exchange (Stock Code: 1208).

The company benefits from an experienced international management team and the support of the majority shareholder China Minmetals Corporation.

MMG currently owns and operates the Century, Golden Grove and Rosebery mines in Australia, the Kinsevere mine in the Democratic Republic of Congo (DRC) and the LXML Sepon mine in Laos.

Major development projects include Dugald River, an undeveloped zinc-lead-silver deposit located in north-west Queensland, Australia, and the Izok Corridor base metals project in Nunavut, north-west Canada.

MMG also has significant exploration projects and partnerships in Australia, Africa and the Americas.

MMG is one of the world's largest producers of zinc and also produces significant amounts of copper, lead, gold and silver.

MMG is committed to achieving long-term sustainable growth and shareholder value. They seek to align with international best practice in sustainability and, as an International Council on Mining and Metals (ICMM) member, they benchmark their performance against the sustainability criteria of the ICMM's Sustainable Development Framework.

MMG is also a member of the Minerals Council of Australia, the Mining Association of Canada and other regional industry organisations.

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7.1 REGULATORY CONSIDERATIONS

7.1.1 A brief history of occupational health and safety laws in Australasia

THE COLONIAL INFLUENCE

Occupational health and safety (OH&S) laws in Australasia have been heavily influenced by our colonial history. The development of workplace health and safety laws during the 19th century to meet the needs of Britain's industry flowed on to the Empire and later, to members of the Commonwealth.

In the early days legislation was developed to address industry-specific issues such as the *British Cotton Factories Regulation Act 1819*, which set the minimum working age at nine years and maximum working hours at 12, and the *Mining Act 1842*, which prohibited females from working in mines.

Typically, these early laws were aimed at specific risks and were prescriptive in nature. In Australia, the growth of the various colonies in the late 18th and early 19th centuries was underpinned by the discovery of coal, base metals and gold.

Coal was first discovered in New South Wales (NSW) in 1791. Discoveries increased significantly as the early explorers opened up the continent, followed by the farmers and prospectors. These discoveries included gold at Bathurst, NSW and Clunes, Victoria in 1851; copper/gold at Cobar in 1859; copper at Moonta, South Australia in 1861; gold at Rockhampton, Queensland in 1866; gold at Birdwood, South Australia in 1870; and gold at Halls Creek, Western Australia in 1885. Of particular note were the discoveries at Broken Hill and Coolgardie in 1892, which led to the development of sustained mining activity that underpinned the economic future of Australia.

The need to develop laws to control the industry quite naturally led to legislation modelled upon the British statutes of the time. As mineral deposits were discovered in New Zealand and Papua New Guinea, similar legal frameworks were adopted. In Australia, provisions for the appointment of inspectors of mines and the associated legislation came into place in the late 19th and early 20th centuries, for example in New South Wales the *Mines Inspection Act* commenced in 1901.

In the case of Papua New Guinea, Australia took over the governance of the British territory in 1906, and independence from Australia was only attained in 1975. In 1977, the *Mining (Safety) Act 1977* covering the mining industry was enacted. Prior to this, the Mining (Safety) Regulations 1935 applied to manage OH&S in the Papua New Guinea mining industry.

ROBENS APPROACH TO OCCUPATIONAL HEALTH AND SAFETY

The most significant changes in mining OH&S law came with the 1972 publication of the United Kingdom (UK) report of the Committee on Safety and Health at Work, better known as the Robens Report. This report recommended a move away from industry-specific prescriptive legislation in favour of performance or outcome-based laws. Figure 7.1.1 summarises the features of the Robens approach.

Table 7.1.1 summarises the current legislative frameworks within Australasia.

FIG 7.1.1 - Summary of Robens style of occupational health and safety legislation.

Since 1972, the New Zealand and Papua New Guinea governments have adopted, to varying degrees, the Robens approach to mining OH&S legislation.

7.1.2 Model framework for continued improvement in Australia

Society in general has high expectations for the OH&S performance of all industries. For mining, in particular, there is an expectation that OH&S performance will improve and this is emphasised by the 'zero harm' goals adopted in recent times. Some years ago it became apparent that the existing legislative regime was not delivering ongoing improvements at the rate that society has a right to expect. Australian states and territories have differing approaches to OH&S across the industries being regulated, and this is seen as impeding the movement of workforce participants and companies alike.

TABLE 7.1.1
Current legislative frameworks within Australasia.

Jurisdiction	Primary act	Industries covered	Regulations	Industries covered
New Zealand	<i>Health and Safety in Employment Act 1992</i>	All on shore industry	<i>Health and Safety in Employment Regulations 1995</i>	All on shore industry
			HSE (Mining - Underground) Regulations 1999	Underground mining
Papua New Guinea	<i>Mining (Safety) Act 1977</i>	Mining industry (excluding exploration, quarries, oil and gas)	Mining (Safety) Regulation 1935	Mining industry (excluding exploration, quarries, oil and gas)
Australian Capital Territory	<i>Work Health and Safety Act 2011</i>	All industry	Work Health and Safety Regulations 2011	All industry
Indian Ocean Territories	Regulated by DMP WA under an agreement with the Commonwealth	Mining industry	Regulated by DMP WA under an agreement with the Commonwealth	Mining industry
New South Wales	<i>Occupational Health and Safety Act 2000</i>	All on shore industry including all mines and quarries	Occupational Health and Safety 2001	All on shore industry including all mines and quarries
	<i>Coal Mine Health and Safety Act 2002</i>	Coal mines	CMH&S 2006	Coal mines
	<i>Mine Health and Safety Act 2004</i>	Metalliferous mines and quarries	MH&S 2007	Metalliferous mines and quarries
Northern Territory	<i>Workplace Health and Safety Act 2007</i>	All onshore industries up to the mean low water mark	Workplace Health and Safety Regulation	All onshore industries up to the mean low water mark
	<i>Dangerous Goods Act</i>		Dangerous Goods Regulations	
Queensland	<i>Mining and Quarrying Safety and Health Act 1999.</i>	Metalliferous mining and quarrying	Mining and Quarrying Safety and Health Regulation 2001.	Metalliferous mining and quarrying
	<i>Coal Mining Safety and Health Act 1999</i>	Coal mining	Coal Mining Safety and Health Regulation 2001	Coal mining
Tasmania	<i>Workplace Health and Safety Act 1995</i>	All, with some mining specific parts	Workplace Health and Safety Regulations 1998	All, with some mining specific parts
South Australia	<i>Occupational Health Safety and Welfare Act</i>	All on shore industry	Occupational Health Safety and Welfare regulations	All on shore industry
Western Australia	<i>Mine Safety and Inspection Act 1994</i>	Mining industry	Mine Safety and Inspection regulations 1995	Mining industry
Victoria	<i>Occupational Health and Safety Act 2004</i>	All on shore industry	Occupational Health and Safety regulations 2007	All on shore industry

In 2002, the Conference of Chief Inspectors of Mines started developing seven strategies, aimed at providing the mining sector with a framework for continued improvement into the future. A major component of this was ‘Strategy 1: Nationally consistent legislation’. This work was taken over in 2005 by the National Mine Safety Framework (NMSF) steering group, a tripartite committee set up under the auspices of the Ministerial Council for Minerals Petroleum and Resources (MCMPR).

The Productivity Commission 2006 report, *National Worker’s Compensation and Occupational Health and Safety Frameworks* (Australian Government Productivity Commission, 2006), provided recommendations to the Council of Australian Governments (COAG) for the development of harmonised OH&S legislation in Australia.

In July 2008, COAG, through an Intergovernmental Agreement (IGA), committed the states, territories and Commonwealth to working together to develop and implement model work health and safety laws.

On 3 April 2009, the Workplace Relations Ministers’ Council (WRMC) endorsed the creation of Safe Work Australia, a new independent body to drive the development and implementation of the model work health and safety laws.

The NMSF steering group is working with Safe Work Australia to develop the mining specific parts of the new legislation. IGA required that, by 1 January 2012, each state and territory will have enacted mirror legislation of the model legislation developed by this process. The deadline was met by the Australian Capital Territory (ACT) and the Northern Territory and all other jurisdictions experienced delays in the process. Each jurisdiction is at liberty to implement the new OH&S legislation within current frameworks and some have specified individual components of the model that will not be adopted.

With the amalgamation of the Safe Work Australia and NMSF processes, the mining-specific components of the model legislation split into two separate but related processes. This was driven by the fact that the various jurisdictions have differing legislative frameworks. This is most noticeable in the states of New South Wales, Queensland and Western Australia, where key components of the framework are separate from those that apply to general workplaces and to those in the Northern Territory, South Australia, Tasmania and Victoria, where mining is regulated under the safe legislative instruments as general workplaces.

This situation gave rise to core and non-core processes. The end result was that all Australian jurisdictions were able to agree to a set of core drafting instructions. These were then added to by the non-core process, which provides for areas such as underground coal mining and statutory positions at mining operations.

The following three sections to this chapter outline the fundamental aspects of the new harmonised legislation being developed and implemented in Australia. Adoption of the model legislation may vary from jurisdiction to jurisdiction as there are different legislative frameworks into which it has to be applied. Ultimately the take up and form in which the model legislation is adopted is a matter for the individual states and territories.

7.1.3 Roles, functions and powers under the model Australian legislation for mining operations

RESPONSIBLE ENTITIES AND PERSONS

The model Australian legislation prescribes a hierarchy of responsible entities and persons for mining operations:

- *Person conducting a business or undertaking* (PCBU) is any corporate body or natural person that engages in work or causes work to be undertaken in a workplace. The PCBU concept includes any corporation, limited liability company, contractor or sole trader that engages in work or causes work to be undertaken in a workplace.
- *Mine holder* is a PCBU or natural person that owns the rights to conduct mining operations at a mine.
- *Mine operator* is a PCBU or natural person that conducts mining work at a mine. A mine holder is deemed to be the mine operator unless the mine holder appoints another entity or person to the position of mine operator and that entity or person has accepted the appointment in writing.
- *Senior site executive* (SSE) is a natural person who has authority and control of the mining operation. The SSE is appointed by the mine operator and must be the most senior person who is involved in the management of work at the mine site. To be eligible for appointment as an SSE within the three major mining states of New South Wales, Queensland and Western Australia, the nominated person must hold recognised risk management competencies and have passed a law exam as defined by the board of examiners.

STATUTORY POSITIONS

Statutory positions are not a provision of the legislation within all jurisdictions. Within Australia the three major mining states of New South Wales, Queensland and Western Australia all have a legislated requirement for a number of mining positions (Table 7.1.2).

TABLE 7.1.2

Statutory positions under model legislation for mining operations in New South Wales, Queensland and Western Australia.

Category and statutory position		Coal operations		Metalliferous operations	
		Underground	Surface	Underground	Surface
Mandated positions with practising certificates	Senior site executive	X	X	X	X
	Underground mine manager	X		X	
	Surface mine or quarry manager		X		X
	Undermanager	X			
	Underground supervisor			X	
	Deputy	X			
	Open cut examiner		X		
	Electrical engineering manager	X			
	Mechanical engineering manager	X			
Mandated positions with specified competencies	Electrical supervisor		X	X	X
	Mechanical supervisor		X	X	X
	Mine surveyor	X	X	X	X
	Fire officer	X			
	Roadway dust sampler	X			
Non-mandated positions	Shot firer	X	X	X	X
	Vent officer	X	X	X	X
	Supervisor	X	X	X	X
	Radiation safety officer			X	X

These are consistent across the three states and a tripartite body has been formed to make recommendations on the positions, qualifications and experience that are required.

There are mandated positions that require a practising certificate issued by a board of examiners, and others that must be filled with persons holding specified qualifications and experience. The duties and functions of each position are described within a schedule included within the regulations.

THE REGULATOR

The regulator has the following functions under the legislation:

- advise and make recommendations to the Minister and report on the operation and effectiveness of the legislation
- monitor and enforce compliance with the legislation
- provide advice and information on work health and safety to duty holders under the legislation and to the community
- collect, analyse and publish statistics relating to work health and safety
- foster a cooperative, consultative relationship between duty holders and the people to whom they owe duties and their representatives in relation to work health and safety matters
- promote and support education and training on matters relating to work health and safety
- engage in, promote and coordinate the sharing of information to achieve the objectives of the legislation, including the sharing of information with a corresponding regulator
- any other function conferred on it by the legislation.

The legislation provides the regulator with the necessary power to do all things necessary or convenient to be done for, or in connection with, the performance of the above functions.

FUNCTIONS AND POWERS OF THE INSPECTOR

The functions of an inspector relate to those of the regulator, who has the power to appoint inspectors under the legislation. The inspector's functions are to:

- provide advice and information about compliance with the legislation
- assist in the resolution of work health and safety issues at workplaces
- assist in the resolution of issues related to access to a workplace by an assistant to a health and safety representative
- assist in the resolution of issues related to the exercise or purported exercise of a right of entry by a union
- review disputed provisional improvement notices
- require compliance with the legislation through the issuing of notices
- investigate contraventions of the legislation and assist in the prosecution of offences
- attend coronial inquests in respect to work-related deaths and examine witnesses.

In addition to these functions, inspectors have significant powers to enter workplaces and, upon entry, to conduct investigations. When exercising the power of entry, an inspector is not required to provide notice of intent to enter and is not restricted by time or location where the inspector reasonably suspects that that place is a workplace. Upon entry, the inspector is required, within a reasonable time, to notify:

- the person who is apparently in charge of the workplace
- any PCBU at the workplace
- any health and safety representative present at the workplace who represents the workers conducting work for the PCBU.

Upon entry an inspector has a broad range of powers that enable them to:

- inspect, examine and make inquiries at the workplace
- inspect and examine anything, including documents and records at the workplace
- bring to the workplace and use any equipment or materials that they may require including photographic and recording equipment
- take measurements, conduct tests and make sketches or recordings
- take and remove for analysis a sample of any substance or thing without paying for it
- require a person at the workplace to give the inspector reasonable help to exercise the inspector's power
- exercise any compliance power or other power that is reasonably necessary to be exercised by the inspector for the purposes of the legislation
- require a person to tell the inspector who has custody of, or access to, a record or document
- require a person who has custody of, or access to, a record or document to produce that record or document to the inspector while the inspector is at that workplace or within a specified period
- require a person at the workplace to answer any questions posed by the inspector
- make copies of, or take extracts from, a record or document that has been given to the inspector in accordance with a requirement under the legislation
- keep the record or document for the period that the inspector considers necessary
- seize anything at the workplace if the inspector reasonably believes that the thing is evidence of an offence against the legislation.

An inspector may also require a person to provide their name and address if the inspector finds the person committing an offence against the legislation.

7.1.4 Management, plans and records under the model Australian legislation for mining operations

MANAGEMENT OF SAFETY

Within all Australian jurisdictions the legislation provides for the following:

- an overarching work health and safety management system (WHSMS)
- a formal hazard identification process
- a formal risk assessment process
- the identification of principal hazards, which are risks that have the potential to cause multiple fatalities or repeated single fatality events
- the provision of principal hazard management plans (PHMPs).

The three major mining states also require the provision of principal control plans (PCPs) to manage the risks arising from the aggregation, or interaction between hazards and controls arising out of mining operations. The model legislation prescribes:

- an electrical engineering management plan (EEMP)
- a mechanical engineering management plan (MEMP)

- a ventilation control plan (VCP)
- an explosives control plan (ECP)
- a health control plan (HCP)
- an emergency response plan (ERP).

PCPs form part of the WHSMS and thus work at the mine and mining operations must not commence until these plans are in place.

Each of these processes and plans must be commensurate with the size and scope of the mining operations that they relate to, and each worker who is involved or affected by the process or plan must have the requisite training and knowledge of their individual duties that are required to ensure that the processes and plans are effective.

The model Australian legislation prescribes the following nine principal hazards:

1. ground control
2. inundation and inrush
3. mine shafts and winder operation
4. roads and other vehicle operating areas and traffic management
5. air quality, airborne dust and other airborne contaminants
6. fire and explosion
7. gas outbursts
8. ionising radiation
9. spontaneous combustion.

This framework, illustrated in Figure 7.1.2, requires a formal hazard identification and risk management process that informs an overarching health and safety management system containing principal hazard management plans and principal control plans, thus reducing the need for prescriptive regulations. Under this model it is envisaged that each individual operation will have the flexibility to adopt the best solution to the issues that are apparent. Such flexibility cannot be provided for under a prescriptive legislative framework.

FIG 7.1.2 - The new model legislative framework for Australian mines.

The net result of this approach is that, in most cases, the new model legislation no longer has specific regulations addressing distinct mining activities, such as ore handling or underground development. The mine operator is required to implement suitable policies and procedures in such areas of activity that manage the associated risks and produces an acceptable level of performance.

WORK HEALTH AND SAFETY MANAGEMENT SYSTEM

A WHSMS must have the following attributes:

- a comprehensive and integrated system for all control measures adopted in accordance with the risk management obligations under the legislation
- arrangements for eliminating and, where not reasonably practicable to eliminate, minimising the risks to the health and safety of persons arising from the use of contractors in mining operations in accordance with the hierarchy of controls
- arrangements for eliminating and, where not reasonably practicable to eliminate, minimising the risks to the health and safety of persons arising from the coordination of the activities of other persons conducting a business or undertaking at the mine in accordance with the hierarchy of controls
- arrangements for conducting health monitoring of workers in relation to any potential exposure of any worker to a hazard arising from mining operations where it is reasonable to expect that the exposure may result in an adverse health effect to the worker
- arrangements for eliminating and, where not reasonably practicable to eliminate, minimising the risks to the health and safety of persons arising from the use of explosives in mining operations
- a management structure of competent persons for the effective management of health and safety at the mine including having persons acting-in, and the timely filling of, vacant positions in the management structure where necessary
- arrangements for setting out the controls implemented to eliminate and, where not reasonably practicable to eliminate, minimise the risks to health and safety arising from hazards and principal hazards at the mine in accordance with the risk management obligations under this regulation
- arrangements for making the WHSMS available for
 - access by workers at the mine
 - inspection by the regulator
- the mine operator must review and revise the relevant components of the WHSMS at least every three years if
 - there is a material change to the mining operations
 - any material modification is proposed at the mine, before the material modification occurs
 - a notifiable injury or illness to a person results from exposure to a risk arising from mining operations
 - a worker's duties are changed due to health surveillance results
 - there is evidence that the WHSMS (or part thereof) is no longer valid
 - the mine operator receives a request from a health and safety representative in relation to a health and safety risk.

RISK MANAGEMENT

The mine operator must ensure, so far as is reasonably practicable, that risk management processes and procedures are developed, adopted and implemented in the WHSMS for the mine. The processes require:

- the identification of all foreseeable hazards in the mining operations
- the identification and assessment of all risks arising from each hazard identified
- the elimination of each risk identified so far as is reasonably practicable
- the minimisation of risk so far as is reasonably practicable in accordance with the hierarchy of controls when it is not reasonably practicable to eliminate the risk identified
- the continual monitoring of the effectiveness of the controls implemented, including processes for identifying, reviewing and responding to incidental events
- the documentation of the risk management processes undertaken
- records of the risk management process to be kept for a minimum of seven years.

The mine operator must ensure that appropriate risk assessments are conducted:

- at the design stage of the mine
- prior to the commencement of the mining operations
- at adequate intervals, or stages, during mining operations regarding the nature of the mining operations and the risks associated with such mining operations
- when there is evidence that an existing risk assessment is no longer valid
- when there is a material change in the mine's practices, processes or procedures.

PRINCIPAL HAZARD MANAGEMENT PLANS

Where the mine operator has identified a principal hazard, a PHMP must be developed, implemented and maintained, which:

- provides for the management of all aspects of risk control in relation to the relevant principal hazard
- is set out and expressed in a way that is readily accessible and comprehensible to persons who use it
- states the nature of the principal hazard to which it relates
- describes how a risk assessment will be conducted in relation to the principal hazard
- specifies the results of the risk assessment
- specifies all control measures to be implemented to control risks to health and safety associated with the principal hazard.

The relationship between the WHSMS, hazard identification, risk assessment and principal hazards is illustrated in Figure 7.1.3.

MINE RECORDS

Mine records are essential references to the engineering design, hazard identification, risk assessment, construction, operation and events associated with the operation of a mine.

These records are a valuable source of information that can be used in future design and planning processes that are part of a continued improvement cycle. Without such records, the management of health and safety is made considerably more difficult. An analysis of historical and recent trends can be used to guide the mine operator in developing strategies to minimise harm and maximise production.

FIG 7.1.3 - Relationships between the work health and safety management system, hazard identification, risk assessment and principal hazards.

Australian legislation requires that specific records are kept. These include:

- all notifications given under the legislation
- all reports, findings and recommendations resulting from inspections, investigations, enforcement provisions and monitoring activities
- all directives issued to the mine operator by the regulator
- a record of and reports about serious accidents, potential serious incidents and any low frequency, high-consequence incidents that occur at the mine
- for underground mines, a written record prepared by the outgoing shift supervisor for provision to the next oncoming shift supervisor in relation to health and safety at the mine, including, but not limited to, the state of the mine workings at the time of the shift change over.

The mine record could be a single record, or alternatively several records, and may be kept in hard copy or electronically as long as it is an easily accessible centralised repository of information relating to risk to the health and safety of workers at the mine.

The mine operator must ensure that a copy of the mine record is easily available for access by workers at the mine and that they are kept for a minimum of seven years.

Should a new mine operator be appointed at the mine; the outgoing mine operator must provide the new mine operator with the records for the previous seven years. The mine records are also to be provided to the regulator upon request.

THE ROLE OF CODES OF PRACTICE

An approved code of practice is a practical guide to achieving the standards of health, safety and welfare required under the occupational health and safety legislation.

A code of practice applies to anyone who has a duty of care in the circumstances described in the code. In most cases, following an approved code of practice would achieve compliance with the health and safety duties in the legislation, in relation to the subject matter of the code.

Like regulations, codes of practice deal with particular issues and do not cover all hazards or risks that may arise. The health and safety duties require duty holders to consider all risks associated with work, not only those for which regulations and codes of practice exist.

Codes of practice are admissible in court proceedings under the relevant act and regulations. Courts may regard a code of practice as evidence of what is known about a hazard, risk or control and may rely on the code in determining what is reasonably practicable in the circumstances to which the code relates.

Compliance with the relevant act and regulations may be achieved by following another method, such as a technical or an industry standard, if it provides an equivalent or higher standard of work health and safety than the code.

An inspector may refer to an approved code of practice when issuing an improvement or prohibition notice.

7.1.5 Duties and other requirements under the model Australian legislation for mining operations

PRIMARY DUTIES OF CARE

The model work health and safety laws are directed at the conduct of those who may affect health and safety through their influence over or direction of work and the way in which it is done. The duties of care of each of the contributing parties are related to what they are able to direct, control or influence.

The elements of work that determine the duties of care are:

- where and when the work is done
- by whom the work is done (including their skills and experience)
- how the work is done (systems of work)
- with what the work is done (equipment, parts and ingredients).

Within the organisational structure of a mining operation, there is a hierarchy of duties of care that are interdependent and these are listed in Figure 7.1.4.

The primary role of each duty holder extends beyond the immediate requirements for the specific work to be carried out. For a principal duty holder, this includes the physical and financial resources available for the work, the systems for organisation of the work, the organisation's culture and the relationships with other parties, such as suppliers and contractors. For the individual worker, these include following the organisational procedures set down for the work, using appropriate personal protective equipment and reporting hazards to the supervisor.

The concept of a primary duty of care also extends to those who provide plant, substances or advice that enable the work to be done. It is at the organisational level, rather than the

FIG 7.1.4 - Duties of care standards and relationship to work elements (source: Workplace Relations Ministers' Council, National Review into model OH&S laws: second report to the WRMC (second report), Canberra, WRMC, January 2009, p 54).

individual level, that the matters relevant to health and safety are determined, and work is done for the organisation. For these reasons, the primary duty of care will always rest with a mining operation's executive management and owners.

QUALIFIER OF 'REASONABLY PRACTICABLE'

It is inevitable that people will be exposed to risk in all workplaces. However, it does not follow that such exposure necessarily means that a duty holder has breached a duty of care placed upon them by the model laws. A breach will only occur where the duty holder fails to meet a standard referred to in the specific duty of care.

The primary duties of care are all subject to the qualifier that the duty holder must ensure the relevant matters are adhered to 'so far as is reasonably practicable'.

In determining what is (or was at a particular time) *reasonably practicable* in relation to ensuring health and safety, regard must be had and appropriate weight given to all relevant matters, including:

- the likelihood of the hazard or the risk concerned occurring
- the degree of harm that might result from the hazard or the risk
- what the person concerned knows, or ought reasonably to know, about
 - the hazard and the risk
 - the ways of eliminating or minimising the hazard or the risk
- the availability and suitability of ways to eliminate or minimise the hazard or the risk

- after assessing the extent of the risk and the available ways of eliminating or minimising the risk, the cost associated with available ways of eliminating or minimising the risk, including whether the cost is grossly disproportionate to the risk.

The test for what is reasonably practicable would include reference to:

- industry custom and practice
- available standards such as Australian and New Zealand Standards
- available codes of practice
- recent research findings and journal articles
- allied industry practice.

A key to the reasonably practicable test is the need to assess the risk and availability of controls before considering the costs involved with eliminating, substituting or implementing any other solution.

It should be noted that the ‘principles that apply to health and safety duties’ refer to a duty holder being required to discharge the duty ‘to the extent to which the person has the capacity to influence and control the matter ...’ thereby recognising that control is a limiting factor in determining what can be reasonably done.

WHO WILL OWE THE DUTY?

In all cases a primary duty of care will apply to the PCBUs for whom the work is being done. This is a natural consequence of the control that the owner and operator of a mine exercise on a day-to-day basis. A primary duty will also apply to those who are providing or contributing to (as part of a business or undertaking) the things that enable work to be done. Such contributions are made by consultants, designers, manufacturers or suppliers.

Because individual workers exercise a significantly reduced span of control in the conduct of work at a mine, the duty of care that they are expected to exercise is somewhat less than that of their employer or the mine operator. This reduced duty is indicated as being a duty to take reasonable care compared to the mine operators’ duty to take reasonably practicable care in exercising their duties.

It follows that on a mine site there are likely to be multiple PCBUs, especially on large, integrated operations. Each PCBU will have primary duties and the primary duties may overlap. The failure of one or other PCBU to meet their overlapping duties will not absolve other duty holders from their individual responsibilities.

TO WHOM IS THE DUTY OWED?

A PCBU at a mine must ensure, so far as is reasonably practicable, the health and safety of workers engaged, or caused to be engaged, by them and workers whose activities in carrying out work are influenced or directed by them, while the workers are at work in the business or undertaking.

A worker is defined as any person who carries out work in any capacity for a PCBU. This will include not only the PCBU employees but also any contractor, employees of a labour hire company, apprentices, trainees, students on work experience, or even volunteers who conduct work at the mine for the PCBU.

ELEMENTS OF THE PRIMARY DUTY OF CARE

The specific elements of the primary duty of care that each PCBU owes to the people potentially affected by the work undertaken at a mine are:

- providing and maintaining a safe and healthy work environment
- providing and maintaining safe plant and structures
- providing and maintaining safe systems of work
- ensuring the safe use, handling, storage and transport of plant, structures and substances
- providing adequate facilities for the welfare at work of workers in carrying out work for the business or undertaking
- providing any information, training, instruction or supervision that is necessary to protect all persons from risks to their health and safety arising from work carried out as part of the conduct of the business or undertaking
- ensuring that the health of workers and the conditions at the workplace are monitored for the purpose of preventing illness or injury of workers arising from the conduct of the business or undertaking.

Where multiple PCBUs are conducting work at a mine, each PCBU must comply with the primary duty of care by *ensuring*, so far as is reasonably practicable, the health and safety outcomes. The actual provision of the relevant matters, such as safe plant or safe systems of work may be undertaken by any one of the PCBUs or a third person tasked with doing so.

OFFICERS' DUTY OF CARE

The term 'officer' under the model OH&S legislation has the same definition as it has in the *Corporations Act 2001* and means:

- a director or secretary of the corporation
- a person who makes, or participates in making, decisions that affect the whole or a substantial part, of the business of the corporation
- a person who has the capacity to affect significantly the corporation's financial standing
- a person in accordance with whose instructions or wishes the directors of the corporation are accustomed to act (excluding advice given by the person in the proper performance of functions attaching to the person's professional capacity or their business relationship with the directors or the corporation)
- a receiver, or receiver and manager, of the property of the corporation
- an administrator of the corporation
- an administrator of a deed of company arrangement executed by the corporation
- a liquidator of the corporation
- a trustee or person administering a compromise or arrangement made between the corporation and someone else.

Under these definitions, a statutory position holder such as a quarry manager will, in most cases, not be an officer of the corporation but a worker at the mine.

The duty of officers is to exercise due diligence to ensure compliance by their bodies corporate. Due diligence in terms of OH&S means to:

- acquire and keep up-to-date knowledge of work health and safety matters
- gain an understanding of the nature of the operations of the business or undertaking of the body corporate and generally of the hazards and risks associated with those operations
- ensure that the body corporate has available for use, and uses, appropriate resources and processes to enable hazards that associated with the operations of the business

or undertaking of the body corporate to be identified and risks associated with those hazards to be eliminated or minimised

- ensure that the body corporate has appropriate processes for receiving and considering information regarding incidents, hazards and risks and responding in a timely way to that information
- ensure that the body corporate has, and implements, processes for complying with any duty or obligation of the body corporate under the *OH&S Act 1972*
- verify the provision and use of these resources and processes.

UNDERSTANDING THE BUSINESS RISKS

Due diligence requires that an officer gains an understanding of the nature of the operations of the business or undertaking of the body corporate and to develop an understanding of the hazards and risks associated with those operations.

In practice, due diligence requires that an officer must identify the hazards associated with the high-consequence but low-frequency risks. Due diligence does not require an officer to engage in the routine supervision of work or to interfere with day-to-day management at a mine. Due diligence is limited to a knowledge and understanding of the *principal hazards* associated with a mining operation.

DUTIES OF WORKERS IN RELATION TO OTHER PEOPLE AT A WORKPLACE

Workers are required to take reasonable care of their own health and safety at work, and to take reasonable care that their own acts and omissions do not adversely affect the health and safety of other people at work. Workers are also required to follow any reasonable instruction to comply with OH&S legislation, or any reasonable policy or procedure relating to work health or safety that has been given to them by the PCBU.

This duty is the embodiment of the common law duty of care of employees extended to apply to all workers and transformed into a statutory duty imposing criminal obligations. The test for reasonable care is an objective test, that is, the courts will look at what a reasonable person would have done in the circumstances of the worker, rather than looking at the subjective situation of the worker.

A person at a workplace is not defined within legislation. The intent is to include visitors to workplaces, such as clients, passers-by, relatives and associates of workers as well as trespassers. Since the duty only applies where a person is at a workplace, its scope depends entirely on the definition of workplace. Persons who enter a workplace have the same duty of care as a worker and this will be tested to the standard of reasonable care.

A workplace is defined as a place where work is carried out for a business or an undertaking. This includes any place where a worker goes, or is likely to be, while at work. In the case of a mine site this would encompass all infrastructure above and below ground whether currently in use or not.

CONSULTATION

The Robens Committee stated that:

... the promotion of safety and health at work is first and foremost a matter of efficient management. But it is not a management prerogative. In this context more than most, real progress is impossible without the full cooperation and commitment of all employees ...

... the involvement of employees in safety and health is too important for ... legislation to remain silent of the matter.

... there should be a statutory duty on every employer to consult with his employees or their representatives at the workplace on the measures for promoting safety and health at work, and to provide arrangements for participation of employees in the development of such measures ...

For these key reasons, Robens-style legislation spells out the consultative mechanisms that must be put in place at mine sites, including the election of health and safety representatives and formation of safety committees when requested by members of the workforce.

Under the model legislation, there is a requirement that other stakeholders, such as PCBUs conducting work on the mine, be consulted on matters that have an effect on health and safety outcomes.

The model legislation also prescribes specific occasions when workers must be consulted, such as:

- during the hazard identification and risk assessment processes
- when making decisions in regards to risk management
- when making decisions about the adequacy of facilities for the welfare of workers
- during the development of the WHSMS
- during the development of PHMPs
- at times when the WHSMS is to be reviewed or modified
- at times when the PHMP is to be reviewed or modified
- when proposing to make changes that may affect the health and safety of workers
- when resolving work health and safety issues
- when monitoring the health of workers or workplace conditions
- when making decisions about the provision of information and training to workers
- when making decisions about consultation with workers.

The consultation is tested by the standard of reasonable practicability.

Consultation is expected to have the following outcomes:

- relevant information about the matter concerned is shared with the workers
- workers are given an opportunity to express their views and to raise health and safety issues in relation to the matters concerned
- workers are able to contribute to the decision-making process relating to the matter concerned
- the PCBU takes the views of the workers into account
- the workers who have been consulted are informed of the outcome of the consultation in a timely manner
- where the concerned workers have elected a health and safety representative, that person is involved in the consultation process.

When considering what is reasonably practicable, the following issues should be taken into account:

- the severity of the likely consequences of the matters to be decided upon
- the need for a timely response to the issues raised by the matters to be addressed
- the availability of persons to be consulted, such as safety and health representatives (SHRs) and shift workers

- the need for additional consultation to address the needs of workers absent at the time of the initial consultation, or the provision of additional information relevant to the matters being considered.

HEALTH AND SAFETY REPRESENTATIVES

The legislation gives a broad range of powers and functions to health and safety representative that are aimed at:

- facilitating effective consultation and issue resolution
- monitoring the compliance of the PCBU
- investigating OH&S complaints from members of the work group
- inquiring into risks to the health and safety of workers in the work group arising from the conduct of the organisation.

To facilitate these outcomes, a health and safety representative is entitled to:

- inspect the workplace or part thereof where a worker from the work group works (this may be done at any time having given the PCBU reasonable notice or immediately after an incident or situation that has given rise to a serious risk to health and safety of any person emanating from an immediate or imminent exposure to a hazard)
- accompany an inspector during an inspection of the workplace or part thereof at which a worker or work group works
- with the consent of a worker or group of workers, be present at an interview between an inspector and a PCBU concerning health and safety
- request the establishment of a health and safety committee
- receive information concerning the work health and safety of workers in the workgroup.

Ordinarily, the powers of a health and safety representative are limited to acting within the work group that they represent. However, they may exercise their powers outside of their work group if there is a serious risk to health or safety emanating from an immediate or imminent exposure to a hazard that affects or may affect a member of another work group, and if a member of that work group asks for assistance because their health and safety representative is not available.

A health and safety representative may request external assistance from a person holding a work health and safety entry permit. A PCBU may refuse access to such external persons on 'reasonable grounds' and these may be due to a lack of technical competence in regards to the issues to be resolved or the disqualification from holding a work health and safety entry permit.

Where a health and safety representative has formed a reasonable belief that a contravention has occurred, they may, after consultation with the person to whom a provisional improvement notice is to be issued, issue such a notice.

In relation to health and safety representatives, a PSBU is obliged to:

- consult and confer with the health and safety representatives on the various matters that are set out within the Act
- allow the health and safety representatives to attend interviews
- provide resources, facilities and assistance to enable the health and safety representative to exercise their powers or perform their functions
- allow people assisting the health and safety representative to have access to the workplace
- provide prescribed training.

HEALTH AND SAFETY COMMITTEES

The model legislation provides for the formation of a health and safety committee at a mine where a PCBU is requested to do so by a health and safety representative or five or more workers. Such a committee must be formed within two months of the request. This does not prevent the PCBU from forming a health and safety committee of its own volition.

The functions of a health and safety committee are to:

- facilitate cooperation between the PCBU and workers in instigating, developing and carrying out measures designed to ensure workers' health and safety at work
- assist in developing standards, rules and procedures relating to health and safety that are to be followed or complied with at the workplace
- undertake other functions as prescribed by the regulations or agreed to by the PCBU and the committee.

The health and safety committee must meet at least quarterly or when requested by half or more of the committee membership.

ISSUE RESOLUTION

The model legislation recognises the benefits of timely and effective resolution of work health and safety issues by requiring work participants to engage in processes to achieve that outcome.

Under the legislation, the following are involved in the resolution process:

- each PCBU who is involved in the issue, or their representative
- the health and safety representative of a work group of workers affected by the issue
- if the workers are not in a work group, then the workers or their representative.

Where there is a health and safety representative, the PCBU is required to try and resolve the issue with that health and safety representative rather than with the workers themselves.

The PCBU representative must be a person who is not a health and safety representative and who has the appropriate level of authority and competence to act as the representative of the PCBU.

The legislation does not prescribe in detail the processes to be used in the resolution of issues. Efforts are expected to be reasonable, timely and effective in resolution. This must be undertaken by a procedure that is agreed between the represented parties and where no agreement can be reached then the legislation provides a default procedure that must then be followed.

A union representative holding a work health and safety entry permit may assist in the resolution process.

UNION RIGHTS OF ENTRY

Under various provisions, a *bona fide* union representative has the right to enter a workplace at a mine. Within Australia, the *Fair Work Act 2009* provides for such entry where a member of the workforce is eligible to be a member of the union that the official represents. In states and territories that have adopted the *Safe Work Australia Model Act* in full, this right is also included within the OH&S legislation. Where such provision is made under the OH&S legislation, the union official must be the holder of a work health and safety entry permit to exercise the right of entry. Union officials must have undertaken prescribed training and be the holder of an entry permit issued under the *Fair Work Act 2009*.

The work health and safety entry permit holder may, on entering a workplace to enquire into a suspected contravention:

- inspect any work system, plant, substance, structure or thing that is relevant to a suspected contravention
- consult with relevant workers in relation to the suspected contravention
- consult with the PCBU about the suspected contravention
- require the relevant PCBU to allow the permit holder to inspect and make copies of any document that is directly relevant to the suspected contravention that is kept at the workplace or is accessible from a computer that is kept at the workplace
- warn any person whom the permit holder reasonably believes is exposed to a serious risk to their health and safety (emanating from an immediate or imminent exposure to a hazard).

The permit holder is also required to give 24 hours' notice to the PCBU of the intention to enter the workplace and may only enter parts of the operation where the relevant workers work.

The legislation contains provisions for a permit holder to be disqualified should they breach the rights provided by the permit. A breach may occur where a permit holder:

- intentionally and unreasonably delays, hinders or obstructs any person, resulting in the disruption of any work in a workplace or otherwise acts in an improper manner
- uses or discloses information of a document obtained in the exercise of entry powers for a purpose that is not related to the enquiry or the rectifying of the suspected contravention unless the permit holder reasonably believes that the use or disclosure is necessary to lessen or prevent a serious risk to a person's health and safety or to public health and safety or the disclosure is a necessary part of an investigation or legal process noted in the legislation.

DISCRIMINATION

The model legislation provides that a person is engaging in unlawful discriminatory conduct if, for a prohibited reason, they:

- dismiss a worker
- terminate a contract for services with a worker
- alter a worker's terms of engagement to the worker's detriment
- alter the worker's position to that worker's detriment
- refuse or fail to engage a prospective worker
- treat a prospective worker less favourably than another prospective worker would be treated in offering terms of engagement
- terminate a commercial arrangement with a person
- refuse or fail to enter into a commercial arrangement with a person.

The prohibited reasons are those connected with the involvement of a person who is undertaking a role under the legislation or cooperates or assists another undertaking such roles, and include:

- being or exercising powers or performing functions as a health and safety representative or as a member of a health and safety committee
- performing a function under the legislation, or performing such a function in a particular way

- assisting or proposing to assist or giving information to any person who is exercising a power or function under the legislation
- raising or proposing to raise an issue or concern about health and safety with a PCBU, an inspector, a work health and safety entry permit holder, a health and safety representative, a member of a health and safety committee, or another worker or any other person who has a duty under the legislation or is exercising a power or performing a function under the legislation
- being involved in or proposing to be involved in resolving a work health and safety issue
- taking action or proposing to take action to seek compliance by any person with a duty or an obligation under the legislation.

A person only commits an offence for discriminatory conduct if the prescribed reason was the dominant reason for that conduct.

LEGAL PROFESSIONAL PRIVILEGE

Despite the scope of the powers provided to an inspector, the model legislation provides an express protection of communications, which includes documents that are subject to legal professional privilege.

Information and documents will be privileged if they are created for the dominant purpose of providing legal advice or are in contemplation of legal proceedings. It is now common practice for organisations to engage lawyers immediately after a serious occurrence to advise them in relation to their legal liability arising from the incident.

It is common in such cases for experts to be engaged to conduct investigations on behalf of a PCBU and for the reports related to such investigations to be subject to a claim of legal professional privilege. However, such privilege cannot be claimed over documents and records that existed at the time of an incident whose purpose was not and is not intended for the purpose of providing legal advice or in contemplation of legal proceedings.

IMPACT ON DAILY OPERATIONS

For mining professionals and personnel working in Australian mines the impact of the new harmonised legislation may not be immediately evident. Most will not experience the imposition of greater fines and penalties as a result of being prosecuted; however, when an investigation is undertaken following an incident it can be expected that corporate lawyers will be keen to get involved so as to mitigate against potential prosecution.

For those unfortunates that are more deeply involved in breaches of the legislation the imposition of stiffer penalties will have an appreciable impact. The new laws identify and place high expectations on a variety of persons involved in mining operations. Board members as well as senior management can be expected to be caught up in events following serious accidents. This will also extend to contractors and their subcontractors due to the provision of the PCBU concept within the legislation.

The concept of 'officer' enshrined in corporations law is also now part of the new legal landscape regulating mining operations. This places a significant responsibility couched in terms of 'due diligence' on anybody holding senior corporate positions within a mining or contracting company.

As such all senior managers and corporate executives are expected to take all reasonable steps in identifying the risks associated with the mining operation and to manage them to meet societal expectation. To this end individuals appointed to statutory and supervisory

positions are required to hold appropriate risk management qualifications and to have knowledge of the occupational health and safety laws that regulate mining operations.

The more obvious impacts will be felt at operational levels with the requirements for well-documented processes and procedures forming the work health and safety system, principal hazard management plans and principal operating plans. Many current mining operations will already have much of this material in place; however, there may be a degree of reorganisation and ‘rebadging’ required to attain full compliance with the new laws.

The specific consultation requirements may also present a need to focus on the involvement of workers and in particular health and safety representatives in operational planning and change management processes.

The impact of the new laws will certainly be felt by applicants for ‘Practicing Certificates’ in those states requiring the appointment of suitable persons to statutory positions. The provision of a completely new suite of laws and regulations will place potential candidates on a steep learning curve in order to pass the associated examinations.

In general the ‘less prescriptive’ nature of much of the new legislation will allow mining operators to put in place the best solution to manage the risks at their respective sites.

7.2 MINE PLANNING AND SCHEDULING

7.2.1 Mine planning systems

A comprehensive mine planning system should encompass strategic, business and operational planning activities and processes, aligning the operation with the business goals. Mine planning can be considered on three major levels:

1. Strategic planning: an overall plan to maximise the value from the exploitation of the known and anticipated mineralisation.
2. Business planning: consists of two components; long-term and medium-term planning, both linked to the strategic plan but more detailed. Typically business planning incorporates the annual budget through to the five-year business plan.
3. Operational planning: detailed plans including the rolling three-month forecast, monthly, weekly and daily equipment plans, which guide the operation to achieve the business targets detailed in the budget.

Strategic and business plans should focus on material movements, and equipment and employee requirements are an output from the plan. Operational plans should focus on the detailed equipment and employee plans from which material movements are an output.

A comprehensive mine planning exercise incorporates an extensive list of technical information and interaction with various other technical disciplines. The detailed inputs and interactions will vary depending on the level of detail of the plan under preparation but broadly will entail geology, geotechnical, metallurgical, marketing, maintenance (fixed and mobile plant), infrastructure, production (including historical benchmark performance for validation), survey, environmental considerations and sign-off.

The major components of the mine planning process, which is iterative, are depicted in Figure 7.2.1.

Strategic planning is required to develop and manage the preparation and implementation of an achievable life-of-mine (LOM) plan. The strategic planning process should assess an extensive number of practical options and optimise the economic return from the

FIG 7.2.1 - The mine planning process.

operation. Typically the strategic plan considers technical aspects, such as the cut-off grade and blending strategy, production rate, mining method and materials handling options, equipment selection, mining sequence, mine design and scheduling, mine services requirements, equipment and people numbers, infrastructure requirements, operating and capital cost estimation, economic evaluation and safety and risk assessment. Robust processes (such as a well-defined mine planning process and calendar, alignment meetings, peer review, benchmarking and formal sign-off by stakeholders) should be in place to maintain strategic plan quality, integrity and effectively communicate the strategic plan to all relevant personnel. Reconciliation between planned and actual performance should be measured by appropriate key performance indicators (KPIs).

The business plan should be a subset of the strategic plan and detail the physical and financial targets required to meet the objectives of the organisation. Consequently the business plans should be aligned with the LOM plan. Typically the business plan considers similar technical aspects to the strategic plan but with greater emphasis on the practicalities and implementation. Robust processes should be in place to maintain the quality and integrity of the business plans and ensure they are effectively communicated to all relevant personnel. Reconciliation between planned and actual performance should be regularly measured and monitored using appropriate KPIs.

Operational planning supports efficient mining operations within the context of the business plan. The operational plan is essentially an equipment plan informing the operations group when and where equipment and employees should be operating to achieve the goals of the business plan. The operational plan typically considers production activities to be undertaken on a daily basis through to the three-month rolling forecast. It should also encompass detailed reconciliation, comparing what was actually mined to what was planned to be mined within the operating and business plans. Non-compliance should be reviewed critically and appropriate actions taken to minimise future deviations from the business plan.

7.2.2 Mine scheduling and optimisation

Production scheduling is an integral part of the mine planning process. Mine designs are prepared iteratively, with constant reassessment of the mining schedule. The process is necessarily laborious.

Scheduling is required for the development and production activities in underground and open pit mines. Types of schedules include:

- strategic plans (life-of-mine)
- business plans (five-year plan and annual)
- operating plans (forecast, weekly and/or monthly).

The LOM plan typically considers all Measured and Indicated Resources, and usually assumes a percentage conversion (based on historical experience with appropriate professional judgement) of Inferred Resources. The business plan should be based on Proven and Probable Ore Reserves, although for some mines, such as gold mines with erratic grade distributions, Ore Reserves may never exceed one to two years because of the difficulty of proving them by drilling. The operating plan should be based on Proven Ore Reserves, which in an underground mine should have the primary access development already completed, even if the detailed level and extraction development is not.

Significant advances have been made in recent years in the development of integrated, computerised mine design and scheduling tools. This has enabled greater integration between long-term and short-term schedules, and the ability to optimise mine plans and efficiently meet quality and material ratio targets. Much of the available scheduling software (eg Earthworks Production Scheduler, MineSched) can be readily used in conjunction with the common mine planning systems (eg Datamine, Surpac, Vulcan). The embedded scheduling functions are based on linear programming or other optimisation techniques, such as genetic algorithms.

It can be a trap to develop a very complex long-term model using these systems, because changes that inevitably occur in mining practice render the schedule meaningless, with schedules often being obsolete before they are completed. However, these new tools mean that schedules can readily be updated and numerous options and scenarios evaluated relatively quickly. The integration between the mine design and scheduling software also allows visual inspection and interrogation of the mine plan. Care must be taken by those responsible for the preparation of the schedule to ensure the inputs and assumptions are realistic and outcomes achievable.

Any system more complex than spreadsheets will require a dedicated operator. As with geological modelling systems, constant involvement is required to maintain skill levels after an initial learning period of many months. These are not tools that will reduce the workload of a general mine planning engineer.

Care must be taken to ensure that the scheduling function is well documented and sufficiently simple that staff transfers can be accommodated regularly without total disruption of the planning function.

Most high-level mine scheduling can be done using simplified approaches, and in many cases with the assistance of ordinary spreadsheets, which are very flexible and easily understood by others. Careful consideration should be given to the most appropriate scheduling tools for a particular application as the decision is associated with significant time, cost and effort.

7.2.3 Short- and long-term scheduling

The major considerations of short-term and long-term schedules were described in Section 7.2.1. The main difference between short- and long-term scheduling processes is the amount of detail required to ensure the schedule is practical and achievable. For the reasons outlined in Section 7.2.2, it is not desirable to include any more detail than is necessary.

The objectives of open pit and underground schedules are considered separately as, while there are some similarities, the factors that require considerations can be quite different.

The objectives of open pit scheduling may include:

- providing a steady and balanced ore feed to the mill or a steady blended product, such as iron ore for direct shipping
- maximising the net present value (NPV) of the project by accessing higher grades early and always filling the processing plant with the best available feed
- providing a steady, balanced workload for the ore and waste mining equipment fleets
- deferring the mining of waste as long as possible to minimise the present value of the stripping cost
- defining pushback campaigns to maximise waste mining efficiencies and/or minimise contract mining costs
- combining ore and/or waste blocks to form minimum bench widths so that equipment can operate efficiently and safely, and to avoid the need for costly 'dozing down' to a lower bench
- maintaining haul road access to working benches and maintaining an effective sump
- providing sufficient face length for blending and equipment efficiency
- providing time in the mining cycle for grade control
- optimising the blend of production from two or more pits while managing active and low-grade stockpiles.

Several of the above objectives can be contradictory, so judgement and experience must be applied. All scheduling of mining operations is complex. For example, great precision is required in scheduling dragline stripping operations to minimise cost and specific software has been developed to assist the engineer.

The sequence of activities needed to prepare an open pit LOM schedule is generally as follows:

- optimise the final pit shell
- prepare a detailed design of the final pit including final catch benches, batters and haul road
- re-optimize one or two intermediate pits by increasing costs or reducing product price
- define two or more phases of pit
- development with roughly equal ore and waste volumes based on the intermediate pits
- describe the minimum prestrip required to provide enough face length in ore in the phase 1 pit to permit the design production rate
- schedule ore and waste mining through the pit phases with the aim of satisfying the objectives previously listed
- prepare a series of pit development plans showing how access is maintained, say on an annual basis.

Note that the pit never conforms exactly to the sequence of pit phases; the phases are simply concepts that provide a structured way of deferring waste while maintaining access and safe operating areas. Once this broad schedule has been prepared for the life of the final pit, more detailed schedules are prepared on an annual basis. Usually only the forthcoming year is scheduled in detail on a weekly or monthly basis. To do this, the annual pit development plan is superimposed on the resource block model and quantities are taken off at a height of one flitch or working bench and the limits of weekly digging are shown. In practise, the schedule may show the next month on a daily or weekly basis and then monthly limits thereafter. There is no point in planning in detail beyond the period in which there is confidence in meeting the schedule. For products such as iron ore, which require blending through multiple stockpiles, the scheduler must keep track of the stockpiles as well as mining within the pit. The blending may be driven by minor elements (eg phosphorus) rather than on the percentage grade of the primary product.

The objectives of underground scheduling are similar to those for open pits and some objectives are identical. They include:

- providing a steady and balanced ore feed to the mill or a steady blended product for direct shipping
- maximising the NPV of the project by accessing higher grades early and always filling the mill with the best available feed
- providing a steady, balanced workload for employees and development and production equipment fleets
- deferring development as long as possible consistent with access for exploration, infill drilling and stope development
- setting development rates that are unit multiples of the capacity of a standard development crew or fleet
- minimising the number of active working areas to reduce the cost of supervision and services
- minimising the time development has to be kept open in recognition that there is maintenance cost for development
- maximising the size of stopes or stoping blocks while keeping a minimum number of active stopes to protect against stope outages
- providing time in the development and stoping cycle for surveying, infill drilling, planning, ground support and production drilling
- sequencing the stopes from bottom up or from top down according to the mining method and filling requirements
- minimising the requirement for crown and bridge pillars
- minimising broken stocks, which tie up working capital and ore at risk of re-cementing *in situ*
- sequencing according to geotechnical requirements to control mining-induced stresses
- maintaining ventilation and services as required
- provide a steady usage of backfill and maximise the utilisation of backfill material
- minimise the need to remove development waste (mullock) from the mine.

It is usual to have rules about maintaining development ahead of production. For example, in a longhole stoping operation these might be:

- primary access development two years ahead of production
- stope development one year ahead of production

- production drilling six months ahead of production
- broken stocks three months ahead of production.

In another operation these times might be halved depending on the size of stopes and past experience with interruptions due to massive hanging wall, re-cementing ore or crown pillar failures.

Each longhole stope will have a production profile that includes a build-up, a period of steady production, then a tailing off and final clean-up.

The full rate will be determined not by the absolute size of the stope but by the number of drawpoints and the production mucking capability, including orepass and haulage capacities.

The steps in underground production scheduling are as follows:

- calculate diluted tonnes and grade for each stope
- select the mining sequence, defining primary and secondary stopes and permanent pillars, with the aim of satisfying the objectives previously listed
- redefine stopes if necessary to suit the schedule, for example to provide sloping walls in primaries or to reduce their width to minimise cement requirements
- repeat the above steps if required
- estimate the production profile for each stope and prepare a time line showing how consistent production is maintained
- check the filling schedule and matching the stoping schedule if required
- schedule the necessary development with key points being the provision of ventilation and services
- check the required development rates and modify the stoping schedule if they are excessive.

Underground mine scheduling requires a much greater geological knowledge than open pit scheduling. In an open pit, a statistical approach to ore occurrences may be taken provided the expected tonnage and grade are found 'somewhere on the bench'. An underground mine requires detailed geological interpretation and 'hard' boundaries to the orebody model.

Development rates should be set at some multiple of the capacity of a jumbo or development crew working efficiently with good utilisation. The degree of flexibility will depend on the industrial relations environment and whether multi-skilling exists. There is a modern trend not to distinguish between development and production operators.

The achievable development rate will depend on the manning and equipment, the number of available faces, travelling distance between faces and the ground support requirement. If raise boring is contracted out, schedules should be based on campaigns that minimise mobilisation costs.

The importance of the filling schedule should not be underestimated. A useful measure is the cumulative void, which is the difference between the mining and filling schedules. If this continues to grow then instability or loss of access are likely.

7.3 THE LIFE-OF-MINE PLAN AND OPERATING BUDGET

The LOM plan provides the strategic direction for the mine from the current point to the end of operations, mine closure and final rehabilitation. It is the plan that ensures that the organisation has a holistic focus on where it is going and what the operations will look

like at each stage of activity. The annual operating budget (the 'budget') is a more tactical approach, being a detailed subset of the first years of the LOM plan. The LOM plan is best updated by the middle of the business year (financial or calendar) and the budget then follows later in the business year.

7.3.1 The life-of-mine plan

The LOM plan draws on many aspects of the planning function, including the strategic plan (refer to Chapter 10) and long-term schedule (refer to Section 7.2). The complexity of the plan will vary with site complexity, stakeholder involvement, length of mine life (short duration mines with less than five years may not need a separate budget and LOM plan). The plan will need to take account of the parent company policy and requirements, and the needs of current and future management teams.

Several aspects of the plan will most likely contain confidential information and authors of plans should weigh up the circulation and effectiveness of confidentiality within the circulation list (email versus paper copies) and the need for inclusion of confidential detail. Generally areas of strategy that involve third parties, unit cost and forward price assumptions are often sensitive and care should be taken with the amount of detail included.

LOM plans for smaller companies may be disclosed to financial backers and banks. In larger organisations the individual LOM plans may be consolidated within larger business units. Mine managers are encouraged to understand all of the plan's uses and stakeholders before finalising its content. All planned initiatives should be resourced and financed to ensure the plan is congruent with the mine's ability to deliver against it.

The original LOM plan will often be that in the approved feasibility study, and developing/new mines may well use this as a base to develop the ongoing LOM plan. In operations that do not have a current LOM document and are some years into operations then it is strongly recommended that the mine manager commission the site team to develop a LOM plan for the site. The LOM plan is to a large degree a top-down planning exercise with bottom-up input into actual costs and mine schedule.

A comprehensive LOM plan will include some or all of the detail outlined in the following sections.

EXECUTIVE SUMMARY

This should comprise a summary of the key information of the plan and anticipated outputs.

BUSINESS OVERVIEW AND CONTEXT SETTING

The business overview may include a brief description of the organisation, its battery limits, key strategic objectives, key activities (production targets, projects, exploration activities, third-party dealings, etc), long-term goals, immediate threats and opportunities and significant changes since the last plan.

STRATEGIC PLAN SUMMARY

The inclusion of a full strategic plan may be too lengthy and may be more appropriate as an appendix. The summary should include a statement of strategic objectives (safety, sustainable development, production, financial, etc) and how they will be applied to the mine, a tabular strengths, weaknesses, opportunities, threats (SWOT) analysis, a high level risk summary including mitigating actions, business strategy summary, and details of major initiatives including measurable outcomes and responsible positions/officers.

RISK ANALYSIS SUMMARY

A summary of the higher order risk assessment (individual departments' risk registers will contain operational detail; this is a summary of strategic risks) and mitigation initiatives including responsible position/officer, how success will be measured and in what time frames. Risk management is covered in Chapter 10.5.

MARKET ANALYSIS SUMMARY

The market summary will be commodity driven but should include some commentary on the state of the market, future demand and supply predictions, implications of predicted market balance on future commodity pricing, global economic outlook, supply and demand balance for concentrate versus refined metal (as appropriate), global cost curve behaviour (is the cost curve moving up or down?), government actions that have local/in-country effects, etc. Forward price and exchange rate information may also be included depending on the individual organisation's view of sensitivity to this type of data.

PRODUCTION PLAN

Production plans will most likely cover more than one area, eg one or more open pit and/or underground operations, one or more metallurgical plants (eg wash plant, crushing/screening, concentrator, or even smelters and refineries) depending on the commodity type, and each support area (eg technical services, administration). Each production unit of the mine may have a separate production plan, which is best summarised somewhere in this section of plan prior to reporting into the executive summary.

The production plan should include a summary of any aspect material to the physical output, cost base or revenue. Depending on the operation this might include any or all of:

- exploration plans managed by the mine management team
- statements of Ore Reserves and Mineral Resources, including depletions, additions and major changes since the last plan
- LOM production summary of personnel numbers and physical movements, such as tonnes mined, tonne-kilometre material movements, drilled metres, backfill, grade summary, contained metal / product mined and produced, tonnages treated, concentrate / refined metal / bulk product produced, closure activities.

BUSINESS OUTCOMES

This section summarises the financial plan and expected results, and other strategic initiatives and may include some or all of the following:

- operating and capital costs summaries, sales revenues, cash flows and financial results (cash cost; earnings before interest, taxes, depreciation and amortisation (EBITDA), earnings before interest and taxes (EBIT); net profit after tax (NPAT); cash flow; profit and loss (P&L), etc)
- indicative upside cases for potential expansions, acquisitions or discoveries
- other issues and plans not specifically covered in other areas, including specific closure plans, ongoing environmental management plans and other sustainable development plans, perhaps covering specific health and safety, community engagement, human resources, etc (note: any costs involved in these actions should be covered in the cost summaries above).

7.3.2 The annual operating budget

Individual organisations will have policies on what period the annual operating budget (the ‘budget’) should cover in terms of content and time span. Some may be only three years with monthly detail for the first year only, while others may be five years with up to two years of monthly detail and perhaps year 3 in quarters. In the absence of a policy, it is recommended that a five-year plan with two years of monthly data is prepared to ensure continuity into year 2 when preparing the following year’s budget.

The budget is best developed from a first principles approach from the lower levels of the mine management team and consolidated within each level of management. A budget that is not owned by all levels will be challenging to achieve and belief in the budget is a key ingredient in a mine manager’s success. For this reason top-down approaches in the Australian context are not recommended, in preference to bottom up and a section-by-section build-up.

Individual organisations will also have systems in place for generating the input data, but will tend to consolidate the inputs into the accounting software in use. Input may be in the first instance spreadsheet based, or a combination of spreadsheet and direct input into the management accounting system. As a general observation engineers and technical personnel tend to be more conversant with spreadsheets, and currently available accounting packages have limitations, with few having true spreadsheet capability, therefore some degree of budgeting support may be required where spreadsheet input is to be limited.

In new operations without an operating history the feasibility study will form the basis of the first budget. The management team responsible for the delivery of the operational performance will rarely be the same as the feasibility team, and will have to spend considerable time to gain an understanding of the basis behind the feasibility estimates, and to break these down into more accurate estimates. Where operations are ongoing a budget system and set of actual cost performance data should be available as an experience base to draw on.

BUDGET CONTENTS

The budget is the plan that all levels of the organisation measure themselves against, from foreman/superintendent level through levels of management to consolidation into the business unit or company performance and will, therefore, have several levels of reporting. The budget documentation should essentially follow the LOM plan format but with an emphasis on the first years of the plan, and will therefore include specific detail in all of these areas. Initial sections should include:

- a restatement of the context for the budget
- the main activities and goals for all strategic objectives (including sustainable development goals)
- short-term SWOT analysis and significant risk assessment relevant to the first years of the budget
- Mineral Resources and Ore Reserves changes
- clear explanations of the changes since the previous budget and any deviations from the most recent edition of the LOM plan.

Latter sections (described in the following subsections) should include the physical plans, operating costs, the capital budget and business outcomes. The practices already established (or the mine manager’s preference) will guide the location of plans for the inclusion of sustainable development targets, such as safety, environmental performance, community engagement, human resources, etc.

Individual departments may have very detailed budget documents to outline their plan in sufficient detail to all levels in that department. Department budgets will then be consolidated into a mine budget, and this will be consolidated into higher level business unit summaries for larger companies. Departments should include some commentary, which is best recorded as their budgets are assembled to explain the thought processes, such as the need for additional personnel, changes in consumables usage, shutdowns, etc so that others who take over roles during the budget period have an understanding of what was intended. This is often regarded as a tedious activity, and the benefit is usually for others who are not doing the writing, but is nevertheless an important part of planning. These records will usually be in the form of notes in a word document, comment cells in spreadsheets or databases, or speakers notes in PowerPoint slides.

It is considered good practice that all graphical and tabular comparisons also include data for the two years prior to year 1 of the budget (ie the forecast for the current year and the previous year's actual results) to show trends and highlight consistency and areas of change. The size of the mine and company will also have a bearing on how complex the budget documentation is required to be and how many levels of consolidation may be appropriate.

BUDGET PHYSICALS

The mine schedule is the next key step upon which the physical drivers of output and cost are dependent. The physical schedules cover details from planning, mining operations, ore treatment, and should include realistic allowances for ore losses, mill recoveries, etc to derive the sales quantities anticipated, and work in progress (WIP) and stockpile changes over the budget period with a particular emphasis on year 1.

If the schedule is overly optimistic or does not include allowances for risk, then the management team will struggle to achieve the budget (physicals and/or costs). Similarly, if the schedule is too conservative then it will be easily achieved and exceeded, which may lead to imbalance within the organisation and lost opportunities. One of a mine manager's challenges is the balance between realism and pressure to maximise budget outcomes. Some issues for a mine manager to consider in this balance include:

- optimistic schedules not allowing for ore losses from stope failures or pit wall failures (particularly in the later stages of a pit), or weather delays from wet seasons may lead to budget pressure from the outset
- mines over-achieving budget ore production placing pressure on a concentrator or transport network that is under-prepared (eg rail constrained mine)
- concentrators out-performing their budgeted capacity, placing pressure on mines to over-produce budget, in turn leading to short-term decision making, eg mining stopes out of sequence, delaying backfilling or delaying the start of a pit wall cut-back.

An interpretation of the 80/20 rule implies that 80 per cent of the costs will be derived in 20 per cent of the cost centre areas, and these should have accurate first principles estimates derived. The remaining cost items will be less significant and can be estimated from past performance as monthly allowances.

The physicals should be matched to the mine process flows and organisational chart so that foreman/superintendent level have a clear understanding of their physical targets, and can assist with the estimation of the resources and costs required to achieve these targets. Physicals are then summarised as the budget level moves upwards in the organisation with less detail shown, but without loss of the basis behind the budget. The physicals eventually consolidated into a mine manager's presentation upwards should only show those that are

material to the mine's overall performance, and judgement is required to balance the level of detail with the requirements of the reviewing committee.

In preparation for costing, the detailed schedule of tonnes, grades, material movements, etc needs to be broken down into every step in the process, and actual work done and resources required to achieve targets estimated, eg metres of underground development will require metres drilled by jumbos; engine hours for loaders, trucks and ancillary equipment; and consumables per metre for drilling, ground support, explosives, ventilation, pipes and cables, etc. The preceding physical KPIs may be built into contract rates if the mine uses a principal contractor to undertake mining activities.

Crushing and grinding would include throughput tonnes between mantle/jaw changes and re-lines, so that these can be planned to the month. Total movements are divided by productivities, eg total metres drilled divided by a drill's capacity per month to determine the number of drills required for each month, monthly tonnes to be loaded divided by the tonnes per hour to determine total monthly loader engine hours and therefore the number of units required each month.

This is then broken down to the next level (eg loaders will have diesel, ground engaging tools (GET), tyres and maintenance costs, including maintenance and operating labour) per hour of use. Maintenance costs for front line equipment can be based on actual activity, eg metres for drills, tonnes or engine hours for loaders, tonnes-kilometres for trucks, tonnes for conveyors, chutes and mills, hours for pumps and cyclones, etc. There will be residual costs based on monthly allowances, and many minor areas where there is no value in low level estimation; however, this should be limited to no more than 20 per cent of total costs if practical.

The above detail of the budget belongs in spreadsheets and accounting packages, with only high level physicals that drive costs being reported in graphs and tables in the budget documents.

BUDGET OPERATING COSTS

The mine's processes are often used as the basis behind the costing system, but the organisational chart and levels of responsibility can also be used in smaller mines. Cost systems (refer to section 7.3.3 on cost code systems) will generally include expense elements (what the cost relates to, such as labour, consumables, etc), and process or cost centres, which describe where the cost was incurred, eg mining (development, drill and blast, load and haul), milling (crushing, stockpiling, flotation, carbon-in-pulp, filtering, tailings dam, etc), technical services or management overheads. Some more complex operations may also include responsibility codes within a process centre so that individual positions can drill down into their cost performance within a cost centre where more than one responsible person costs into that centre.

Readers are encouraged to refer to the relevant chapters in the AusIMM's *Cost Estimation Handbook* (Noakes and Lanz, 1993) for a more detailed approach to developing costs. Wherever possible cost drivers and known unit costs should be linked to physical schedules so that:

- key inputs are only included in one input place, such that any change can be automatically updated throughout the budget, eg contractor rates, the cost of power, diesel and all known consumables, such grinding balls and reagents
- key cost drivers and productivity estimates (eg tonnes per drilled metre, tonne-kilometre per engine hour, grinding media consumed per tonne of ore) can be adjusted

in one place so that any change to a physical schedule or productivity number will be reflected in the budget estimates.

If done well any change in a schedule or cost driver will automatically recalculate this effect in costs and report this in the business outcomes. Good practice derivation of budget cost estimates continues the linking of production and known productivities or usage factors:

- Ensure the physical schedules are broken down into the same areas as the costing system (cost centres, responsibilities and processes). Equipment hours, consumables usages and productivity numbers described in the previous section are key inputs, with physicals and costs often processed in a seamless approach rather than as the two stages outlined in this chapter.
- Employee numbers are then derived from the physical plans based on measured productivity or past experiences. In new operations where there is little history then values may be taken from judgement or benchmarking. Wherever possible employee numbers should be linked to production through productivity numbers.
- Employee costs are derived from combining estimated numbers with employee rates, including on-costs, for award, staff and labour hire contractors. Employee numbers should also reflect allowances for sick leave, annual leave, training and turnover in total numbers required. Some companies prefer to discount the total employee costs for unfilled vacancies.
- Maintenance labour costs may be reallocated to individual equipment or cost centres based on productivity numbers (eg fitter hours per engine hour, planned maintenance tasks, breakdown allowances, etc) but no more than 80 per cent of available labour should be allocated to allow for shift changes, crib times and training and this forms a key check on total maintenance labour numbers in the budget. The recovery rate may be high enough to recover a maintenance department's full cost, or only the actual work done, at the discretion of the mine manager.
- Consumables costs should be based on the physical usage of consumables from past experience per metre drilled, tonne, engine hour, plant hour, etc and then have the cost of consumables applied to ensure that both usage (volume) and cost effects are separately covered.
- Service contractors should be estimated based on the contract service delivery first and the contract rates second.
- Plant shutdowns and non-routine maintenance should be estimated as separate projects and then included in the budget. These may require high material costs in the lead-up, and high labour costs during the event and should not be smeared over the course of the year.
- Services, utilities and distributions include allocations for power, water, telecommunications, waste disposal, insurance, council fees, etc. Service delivery from internal departments may include information technology (IT) charges, fly-in, fly-out (FIFO) and accommodation costs, etc. There may be an iterative process with internal distributions.
- General overheads include printing, stationery, software license maintenance, corporate office recoveries, etc. There may also be some revenue items recovered from other operations or joint venture partners that need to be included in the budget costs.

CAPITAL BUDGET

Capital can be classified into expansionary and sustaining categories, with expansionary generally being for larger projects with a significant expansion in capacity or mine life.

Examples of expansionary capital may include development of a new underground mine, additional concentrator capacity to increase throughput rates, or the acquisition of a nearby deposit. Expansionary capital is generally individual in nature and its justification is not usually part of the annual budget cycle but rather from a feasibility study (refer to Chapter 6), but capital from approved projects may well form part of the non-sustaining capital budget, and is generally not required to be reapproved as part of the budget cycle.

Sustaining capital is generally required to maintain the asset capacity of the mine (including minor improvements) and to achieve the company's strategic objectives. Departments need to estimate items such as capital development, mobile equipment replacement (and rebuilds if company policy is to capitalise these), and all other discrete normal business items. A general percentage of operating costs may be used for non-specified items (less listed items) in the forward years of the estimate otherwise the forward capital projection will always under call the apparent needs when that year is year 1 of the budget.

The individual budget development for individual capital projects may be based on an operating cost approach, or may be related to construction, procurement and design costs and should include an appropriate contingency, lest the project be approved and then be under funded. The AusIMM's *Cost Estimation Handbook* (Noakes and Lanz, 1993) provides more detail on estimating capital project budgets.

One of the mine manager's challenges is to justify the short-term (year 1 of the budget) sustaining capital budget and to divide up the sustaining capital available amongst the competing requests for capital. This is best achieved through a ranking system with a standard form (eg capital expenditure request or CER) to describe the scope, benefits, risks of not proceeding, NPV added if appropriate, reliability improvement, intangible contribution to strategic objectives, etc. Priorities may also be given to sustainable development criteria so that projects that seek to mitigate the event of a safety or environmental incident, or for legal compliance, may have a ranking other than NPV based. Other classifications may include cost reduction, value improvement, reliability or throughput maintenance.

There are many ways of ranking capital projects and the degree of complexity will vary with the complexity of the organisation. Small mines may be able to rank capital projects informally, but larger operations will require formal systems. A simple NPV ranking is inappropriate when some requests are for safety improvements or other non-commercial projects. A risk rating based system could combine the benefit (consequence) and likelihood of achieving that outcome to arrive at a numbered score for each project. An organisation's risk matrix consequence definitions should include outcomes for safety, environmental, business interruption, property damage, reputation damage, etc to assist with defining the consequence rating. This can be supplemented by similar positive outcomes, such as improvements in community image, or other potential value improvements, rather than only loss measures.

Another method of rating projects is to give them a rating score based on the contribution to the business unit or the organisation's strategic objectives and level of contribution to these. Table 7.3.1 gives an example of this where the strategic objectives each have a weighting and a contribution multiplier (eg 100 for a high contribution, 66 for a medium, 33 for low and 0 for no contribution) to be used for each project. In the example in the table the project has contributions to four of the seven listed strategic objectives. The mine manager can substitute the strategic objectives; adjust the weightings, etc to suit the operation and company situation.

TABLE 7.3.1

Example of a sustaining capital ranking system based on a strategic objectives approach.

Strategic objective	Strategic weighting	Impact score	Ranking score
Health and safety	20%	Low impact (33)	6.60
Environmental performance	15%	No impact (0)	0.00
Social responsibility	5%	No impact (0)	0.00
Development of people	5%	Low impact (33)	1.65
Asset utilisation/productivity	15%	No impact (0)	0.00
Cost competitiveness	30%	Medium impact (67)	20.1
Value creation	10%	Medium impact(67)	6.70
Total	100%		35.05

BUDGET OUTCOMES

The physical and cost estimates are consolidated into the business outcomes both strategically and financially. Financial outcomes begin with ore production (tonnes, grade, contained metal), and concentrator production of saleable products (tonnes concentrate, ounces of gold, tonnes bulk product) tonnes, grades and contained or payable metal. These are combined with cost and exchange rate forecasts to derive sales revenues.

The cost of goods sold is derived from operating costs, and combined with capital expenditure and depreciation/amortisation schedules provide the mine's cash cost, EBITDA, EBIT, NPAT, P&L and cash flow forecasts.

Depending on organisation practice, the budget outcomes may be presented on their own, as comparisons against the current year forecast, and/or against the previous year 2 budget, to demonstrate continuity in the budget plan and to explain changes over the year. Waterfall graphs are a good means of explaining variances between plans.

Other strategic goals may be reported as business outcomes where not covered in the initial sections of the budget.

7.3.3 Cost code systems

Cost code systems or charts of accounts are essential to the orderly presentation of costs incurred, which in turn leads to control of costs and management thereof. An effective costing system enables costs and activities to be analysed to establish cause and effect understanding at decision-maker level. Accounting and financial disciplines understand charts of accounts; however, mining related disciplines generally have a poorer understanding. This section aims to explain the logic behind cost codes for non-financial professionals and provides some practical advice for structuring the costing systems for a mine's operating activities. Financial professionals will generally own the cost coding system, but it is always useful for the operational areas to design their sections of the system.

The mine's operations firstly need to be broken down along functional lines, which usually mirror closely the upper levels of the organisational chart, into high level parent cost centres, summarising lower level cost centres or process codes, to define where a cost is being incurred. These are then assigned appropriate expense elements to describe what the cost transactions actually relate to. In some cases, where personnel operate over several process codes, an additional level of a 'responsibility' code will enable individual company officers to filter and inspect just the costs they have responsibility for.

An effective costing system must balance the need for clear cost information with the need for detail. Modern database enterprise software systems that are typically used for mine site accounting packages track all transactions and it is not necessary to cost into fine detail to capture detailed costs. Most accounting systems are capable of dumping transactions into a viewing program or spreadsheet where they can be sorted and analysed; therefore the detail should always be available. It is not necessary to have an extremely detailed cost coding system, but rather one that aligns with the 80/20 rule: 80 per cent of costs will occur in 20 per cent of areas, and tracking the 20 per cent of smaller costs that occur in 80 per cent of potential areas may not add sufficient value. Having a few general cost elements will therefore assist with keeping the cost system to a practical level of complexity.

A practical and effective costing system will have a number of features that enable the reviewer to understand what has been spent, distributed and accrued (using expense elements), in which areas (process or cost centres), and in some cases by which company officer (responsibility codes). Furthermore, the codes used will have an underlying system with freely available explanation so that one could determine any code's place in the mine from examining the code's make up.

Most existing mines will already have their chart of accounts and cost code system in place. For new mines or organisations that do not yet have operating codes in place, or those wishing to review their systems, the following explanation is given as a basis for system design.

Site code

For organisations with multiple mines, the same cost code system may be used on each site with a different precursor to show which site the cost code relates to. The site cost could consist of either numbers or letters, or a combination, with the first letter or number perhaps relating to a geographic region or commodity type.

Profit centres

Some organisations sort their operations into discrete profit centres and ring fence their activities within the organisation by structuring internal sales agreements based on competitive market pricing. In these cases the site code could also be used to distinguish between profit centres.

In essence any mine is generally its own profit centre, but complex sites may further break the mine manager's mine into several smaller internal profit centres with each major section of mining activity, each metallurgical plant, or combinations of these as their own profit centre. This makes sense only where each entity could exist in isolation from the others; examples include: bulk commodities (coal, iron ore); metal mines that are realistically able to determine market-based sales for toll treatment of their ore; or metallurgical plants also being able to purchase for toll treatment ore, and sell product independently of upstream business units such as smelters and refineries. Often a combination of mine and metallurgical plant would make the most practical profit centre. These arrangements are a little more complicated than the standard and are usually only found in large organisations with complex operations.

Responsibility code

Responsibility codes may be appropriate with complex sites where managers, superintendents, foremen, and/or senior technical personnel have various areas of responsibility across several operating activity areas. Each of these roles can be assigned a

unique code and when costs are collected, each transaction will have the responsibility code attached regardless of the transaction's cost centre. Having a system of responsibility codes will enable the position to be identified at a glance, and this code fits between process cost and site code. An example of a three digit responsibility code is included as Table 7.3.2A. Letters and numerals are equally valid in the examples given below.

TABLE 7.3.2A
Example of a responsibility coding system.

First digit	Second digit	Third digit underground mining	Third digit surface mining	Third digit metallurgical plant
1. Mining operations	1. Operational area 1	1. Planning	1. Planning	1. Crushing
2. Metallurgical operations	2. Operational area 2	2. Development	2. Drill and blast	2. Grinding
3. Maintenance operations	3. Operational area 3	3. Production	3. Load and haul	3. Flotation or carbon-in-pulp-
4. Shared operations		4. Backfill	4. Services	4. Filter/tailings
5. Overhead positions		5. Ore handling		
		6. Services		
		9. Management	9. Management	9. Management

It is suggested that the first digit relate to the type of operation with the table giving examples of mining, metallurgical, shared maintenance (maintenance within each operation could be included in that area), other shared operations (eg FIFO costs, warehousing, utilities and other significant distributable areas) and management overheads. Alternatively these could be consolidated into three areas only, being mining, metallurgical and all others.

The second digit can be used to distinguish between different mine, plant or other areas, eg mine 1, mine 2, mine 3. The third digit is used for differing roles in the various areas, where there are numerous groupings that will depend on the size of the operation and the degree to which work is split between roles. Services in an underground mine include pumping, primary ventilation, grading, bulkheads, etc, whereas in an open pit it might include sumps and pumps, grading, water carts, dozing, etc. Further examples for the third digit in smelting might include 1 for feed prep and primary smelting, 2 for secondary smelting/converting, 3 for anode casting and transport, etc. Therefore the responsibility code for a senior planning engineer, a drill and blast superintendent, a flotation superintendent, or a profit centre manager will have the same first and last digit with only the middle digit to indicate a differing location.

Parent cost centres

Parent cost centres are high-level groupings of cost centres in a similar way that parent work orders group levels of work orders in a maintenance system. However, they are not in themselves coded numbers that appear in the transactions' cost coding. Similar to site codes, these cost centres can be any form of numbers and letters, and are often just groupings of cost centres or responsibility codes in an information system hierarchy. Examples might include all open pit costs, concentrator costs, drill and blast costs, or site admin costs. Several layers of parent cost centres can exist depending on the usefulness to each mine.

Again, the more complex the mine the greater the need for levels of parent cost centres. In simpler sites, the use of parent cost centres may be quite limited, or responsibility codes alone may be all that is needed to ensure a consolidated cost report is clear and useful.

Cost centres

Cost centres, sometimes also referred to as process codes, collect costs according to the work flows on the mine, and an obvious system will enable the process to be determined from the code and vice versa. In order to demonstrate a pattern, several tabular form examples that combine into a large mine site (commodity mixing aside) are provided below. Examples of underground metal mines appear in Table 7.3.2B, open pit mines in Table 7.3.2C, various metallurgical plants in Table 7.3.2D and an indication of combined overheads in Table 7.3.2E.

TABLE 7.3.2B

Example of a chart of accounts or cost code system: underground mining.

Digits 1 and 2: mine, metallurgical plant or overhead area	Digit 3: parent cost centre	Digit 4: process	Example cost code Mine 1	Example cost code Mine 2
Mine 1 is an underground shaft mine Mine 2 is an underground decline haulage without backfill	Planning and technical services	Exploration – on site	1111	2111
		Diamond drilling	1112	2112
		Geology	1113	2113
		Geotechnical	1114	2114
		Mine planning	1115	2115
		Survey	1116	2116
		Overheads	1191	2191
	Mine development	Development – vertical	1121	2121
		Development – horizontal	1122	2122
	Mine production	Production – drilling	1131	2131
		Production – blasting	1132	2132
		Production stope support	1133	2133
		Production – loading	1134	2134
		Production – trucking internal	1135	2135
	Backfill	Backfill	1141	
	Materials handling	Ore handling – crushing and conveying	1151	2151
		Ore handling – hoisting	1152	
		Ore handling – decline haulage		2153
		Trucking to ROM		2154
	Services	Pumping	1161	2162
		Primary ventilation	1162	2162
		Compressed air	1163	2163
	Maintenance	Mobile maintenance	1171	2171
		Fixed plant maintenance – mechanical	1172	2172
		Fixed plant maintenance – electrical	1173	2173
	Supervision and overheads	Management overheads	1192	2192

TABLE 7.3.2C

Example of a chart of accounts or cost code system: open pit mining.

Digits 1 and 2: mine, metallurgical plant or overhead area	Digit 3: parent cost centre	Digit 4: process	Example cost code Mine 3	Example cost code Mine 4
Mine 3 is an open pit Mine 4 is a satellite open pit	Planning and technical services	Exploration – on site	3111	4111
		Diamond drilling	3112	4112
		Geology	3113	4113
		Geotechnical	3114	4114
		Mine planning	3115	4115
		Survey	3116	4116
		Overheads	3191	4191
	Drill and blast	Waste drilling	3121	4131
		Ore drilling	3122	4132
		Waste blasting	3123	4133
		Ore blasting	3124	4134
		Production ground support	3125	4135
	Production	Load and haul waste	3131	4131
		Load and haul ore	3132	4132
		Ancillary services	3133	4133
	Materials handling	Trucking to ROM		4154
	Services	Pumping	3161	3161
	Maintenance	Mobile maintenance	3171	4171
		Fixed plant maintenance – mechanical	3172	4172
		Fixed plant maintenance – electrical	3173	4173
	Supervision and overheads	Management overheads	3192	4192

These tables are intended as a guide only, and do not purport to be fully inclusive of all cost processes or to be the single best way. The tables can easily be changed to remove or add mining operations, metallurgical plants and overhead areas, perhaps introduce a maintenance function independent of the operations, etc. Additional mines or metallurgical plants can be catered for with a different second digit in the process code.

It is suggested that cost or process codes in more complex mines consist of four digits, referring to the operational or overhead areas. The first digit will be unique for each major mining operation, metallurgical plant and other major operational area, and the second digit denoting a mining (#1##), metallurgical (#2##) or overhead (#3##). Tables 7.3.2B, 7.3.2C, 7.3.2D and 7.3.2E combine the operational areas summarised as:

- Mine 1 (11##): an underground mine using backfill and a hoisting shaft with conveyor to the ROM
- Mine 2 (21##): an underground mine without backfill and a haulage decline and road training ore to the ROM

TABLE 7.3.2D

Example of a chart of accounts or cost code system: metallurgical plants.

Digits 1 and 2: mine, metallurgical plant or overhead area	Digit 3: parent cost centre	Digit 4: process	Example cost code Gold plant 5	Example cost code Concentrator 6
Plant 5 is a gold plant Plant 6 is a concentrator	Planning and technical services	Technical support	5211	6211
		Assay	5212	6212
	Production	Crushing	5221	6221
		Grinding	5222	6222
		CIP/CIL tanks	5223	
		Flotation		6224
		Filtering		6231
		Gold room	5232	
		Tailings dam	5241	6241
		Product transport	5251	6251
	Maintenance	Mobile maintenance	5271	6271
		Fixed plant maintenance – mechanical	5272	6272
		Fixed plant maintenance – electrical	5273	6273
	Supervision and overheads	Overheads	5291	6291
Digits 1 and 2: mine, metallurgical plant or overhead area	Digit 3: parent cost centre	Digit 4: process	Example cost code Smelter 7	
Plant 7 is a smelter	Planning and technical services	Technical support	7211	
		Assay	7212	
	Primary smelting	Raw materials	7221	
		Feed preparation	7222	
		Roasting	7223	
		Smelting	7224	
	Secondary smelting	Converting	7231	
		Ingot/anode casting	7232	
	Materials handling	Product transport	7251	
	Maintenance	Mobile maintenance	7271	
		Fixed plant maintenance – mechanical	7272	
		Fixed plant maintenance – electrical	7273	
	Supervision and overheads	Overheads	7291	

- Mine 3 (31##): an open pit mine using close to the ROM
- Mine 4 (41##): a satellite open pit road training ore to the ROM
- Met Plant 1 (52##): a typical gold carbon-in-pulp/carbon-in-leach plant
- Met Plant 2 (62##): a typical sulfide concentrator

TABLE 7.3.2E

Example of a chart of accounts or cost code system: shared services and overheads.

Digits 1 and 2: mine, metallurgical plant or overhead area	Digit 3: parent cost centre	Digit 4: process	Example cost code Gold plant 5
Shared services	Sustainable development	Human resources	9311
		Environmental	9312
		Health, safety and training	9313
	Finance	Accounting	9321
		Financing costs	9322
	Overheads	Purchasing and stores	9331
		Utilities	9332
		Fly-in, fly-out	9333
	Engineering	Engineering support	9341
	Maintenance	Shared maintenance	9371
	Supervision and overheads	General manager	9391
		Business development	9392
		Community engagement	9393

- Met Plant 3 (72##): a smelter
- Overheads (93##): a basic list of mine overheads.

The third digit is for a lower level parent grouping, and the fourth is for the process area itself, with each mine or metallurgical plant using the same digit for the same process.

Many cost centre costs are then redistributed to operational cost centres. Redistribution is most effective where a service or support department incurs costs from servicing operational areas (as opposed to pure mine site overheads) where the operational managers should be recognising the cost of these services lest it become a free service with no connection between demand and cost. Many shared maintenance cost centres are often redistributed in this way, as are utilities (power, raw water, compressed air, etc), or shared services (telephone and IT charges, sustainable development costs, etc). When costs are distributed at the end of the month, they are most effectively done with a transfer debit under the same expense element with offsetting credits in the home cost centre to ensure the detail of the costs are not lost and that there is no double counting. The receiving manager will not on the face of it understand all the inputs to the distribution; internal communication is the key to the effectiveness of this activity.

Expense elements

Expense elements describe and group the cost related to, eg labour, consumables, services, contracts, distributions, etc. In the absence of an existing corporate system (highly unlikely) or if the manager desires a system review, it is recommended to use a three digit number in an ordered series to show the type of expense.

Each series should also include some generic expense elements to keep the number in use in any process centre to a practical minimum. The 80/20 rule applies here again with any expense element capturing less than five per cent of costs without a strategic reason should have these costs included in a generic code instead. When selecting the expense elements

a Pareto chart of past expenditures in each operational or support area will demonstrate which expense elements are not collecting sufficient transactions to justify their addition to the complexity of the system. The mine manager is advised to have each operational and support section review their own expense elements, as third parties will often include large details on their own areas, but superficial detail of other areas due to their relative understanding. Hence, for buy-in on the final system, each area needs to run their own analysis and determine which expense elements will account for 80 to 90 per cent of their costs. Some assertive management may be required in negotiating up or down where the recommendations are either far too detailed, or insufficiently detailed.

The following is a guide for a small- to mid-level operation; a more complex operation may break down the non-production consumables into more groupings:

- 100 series: employee costs for award, staff and contract labour, eg 101 award labour, 102 trainee labour, 103 apprentice labour, 110 staff labour, 120 for contract labour, 130 for labour on-costs, such as annual leave allowance (130), sick leave allowance (131), long service leave allowance (132), payroll tax (133), superannuation contribution (134), etc. Training, travel and accommodation, and other employee-related costs can begin with 140, 150 and 160 respectively, etc.
- 200 and 300 series for various consumable classifications will provide up to 200 consumables expense elements, which even for a very complex operation ought to be sufficient.
- 400 series: utilities and services such as power, gas, insurance, council rates, information and communications technology (ICT), etc.
- 500 series: for items appearing in a cost centre that have resulted from a bulk distribution from another service area, eg power distribution, phone and IT distributions, etc.
- 600 series for non-labour contractors (service and construction) and consultants.
- 700 series for overheads and management.
- 800 series for income, etc.

Examples

Two examples of a complete cost code generated according to the system described and the tables in this section are included below.

Example 1: A1 123 2132 101, where:

- A1 is the site code: gold (first letter A) in region 1 (second digit)
- 123 is the responsibility code: from a mining operations (first digit 1) superintendent in mine 2 (second digit 2) with drill and blast responsibilities (third digit 3)
- 2132 is the cost centre, being operational area 2 (first digit 2), mine 2 (second digit 1), parent responsibility of production (third digit 3) blasting costs (fourth digit 2)
- 101 is the expense element: labour (first digit 1) for award employees (second two digits 01).

Example a: N3 212 6222 281, where:

- N3 is the site code: nickel (first letter N) in region 3 (second digit)
- 212 is the responsibility code: from a concentrator (first digit 2) superintendent in plant 1 (second digit 1) with grinding responsibilities (third digit 2)
- 6222 is the cost centre, being operational area 6 (first digit 6), concentrator 2 (second digit 2), parent responsibility of production (third digit 2) grinding costs (fourth digit 2)
- 281 is the expense element: consumable (first digit 2 or 3) for grinding media (second two digits).

7.4 MANAGING MINING OPERATIONS

7.4.1 Owner versus contract mining

With the advent of the resources boom in the late 1960s most of the larger-scale resources projects in Australasia were commissioned on an 'owner mining' basis, where the mine owners owned and operated the primary mining equipment. Then, in the 1980s, with the arrival of the gold mining boom in Western Australia and elsewhere, a change occurred – most of the mining activities were carried out on a contract mining basis.

Since then, however, there has been a marked trend amongst larger Australasian open pit mining operations back towards owner controlled and operated mining operations. The reasons for this are many, but centre on the concept of the owner being prepared to assume more of the mining risk in exchange for the advantage of not having to pay a contractor's profit margin.

Where mining contracts are entered into, the older 'schedule of rates' format is being replaced with less adversarial and more entrepreneurial contract alternatives involving operating cost and risk sharing in a spirit of 'fair dealing'. Leasing and maintenance issues have also been influenced in recent years by the advent of more flexible contract arrangements with equipment suppliers. Group purchasing has also had some influence on project operators.

For many mine owners, the optimal risk management profile involves a practical offsetting of the assumption of mining risk on the one hand, against the removal of litigation risk and potentially reduced operating costs on the other. Potential pitfalls may arise where equipment size and type requirements vary with time or where manpower management, mining flexibility, job skills or safety exposure factors are relevant.

A SHORT INTRODUCTION

Owner mining is the now widely accepted term for the mining situation where the mine owner directly controls and has responsibility for the mining activities at the mine. The owner might be a joint venture manager and the mining fleet may be leased rather than owned outright, but the important feature is that a mining contractor is not used.

Over the last decade, there has been a marked trend amongst larger Australasian open pit mining operations back towards owner controlled and operated mining operations, as reported by Bell (2000). Why is this the case? The answer appears to lie in the concept of the owner being prepared to assume more of the mining risk in exchange for the advantage of not having to pay a contractor's profit margin, as suggested by Shipp (2000) and Ready (2000).

Where continuous improvement programs are in place, a point is theoretically reached where an owner and a contractor may have a conflict of interest when it comes to the profit margin, day works and 'extras', when seen from the point of view of ongoing continuous improvement. Notwithstanding that, contract mining may continue to have appeal in certain situations. For example, where the waste movement profile is necessarily variable, and the primary mining fleet sizing needs to be flexible, a mining contract might be more appropriate, as reported at Sunrise Dam (Anon, 2000a). In such situations, industry efficiency and productivity benchmarking initiatives are useful in setting standards to be reached by the contractor.

Likewise, it may be that the project location has such perceived risk that the owner might not be able to obtain finance for its own mining fleet without putting forward significant

financial guarantees (Morobe Consolidated Goldfields Ltd, 2001). It is now apparent that the mining approach taken will depend on the owner's risk management approach. The optimal risk management profile involves a practical offsetting of the assumption of mining risk on the one hand, against the removal of litigation risk and potentially reduced operating costs on the other. Potential pitfalls may arise where equipment size and type requirements vary with time or where staffing management, mining flexibility, job skills or safety exposure factors are relevant.

ALTERNATIVE OPERATING OPTIONS

Broadly speaking, most mining operations may be conveniently broken down into a number of recognisable unit operations. For example, in a surface mining situation, one might begin with operations, maintenance and technical services. Operations might be further broken down into drilling, blasting, loading and hauling; technical services might be broken down into geology, mine planning, surveying and so on.

In theory, any or all of these activities may be contracted out. In order to assess logically what should be contracted out and what should not, a process of evaluation was suggested by Dunn (1998). Dunn, a principal consultant with financial advisors PriceWaterhouseCoopers, suggested that the decision be based on weighing up the factors of cost, benefit and risk.

As a first step, however, one needs to determine what tasks to contract out. Dunn suggested that the criterion should be those tasks that fall into both of the following categories:

- not of strategic or core importance to the owners
- not likely to be carried out competitively if done by the owners.

Most project owners regard areas such as quality control, safety and management as core areas, which should not be contracted out. In general terms, this leaves three areas under consideration, namely, plant ownership (lease rather than purchase); contract mining (drill and blast or load and haul, or both); and maintenance. Dunn outlines in his paper eight critical success factors (CSFs), set out below:

1. grade control
2. production costs
3. health and safety
4. people management
5. productivity
6. production output
7. continuous improvement
8. environmental management.

The paper then provides a quantitative method of assessment for each of these CSFs, in terms of both benefits and risks. These comparative rankings, when combined with the cost comparison, complete the three tiered evaluative approach.

In the example quoted by Dunn, the benefits assessment favoured owner mining (scored at 73 per cent) by 22 points (contracting scored 51 per cent). Similarly, in the area of risk assessment, the owner mining risk index was lower than that for contract mining.

The decision to contract out the fleet ownership (ie to lease the fleet) will be determined by project capital cost constraints in most instances. Similarly, most operations will wish to retain control of the core areas of management and technical services (though it may decide to contract out some subcomponents such as survey and assaying). That leaves the areas

of mining and maintenance. Few resource project operators could claim that maintenance activities would be core to their potential success. In most cases, this area is either contracted out to the earthmoving contractor (if there is one), otherwise to the original equipment manufacturer (OEM).

The ground fragmentation and earthmoving activities are always less clearly suited to either contract or owner controlled operation. In general a range of project specific factors will determine which alternative attracts the preferred risk and benefit profile:

- drilling – may require a specialist contractor if not straightforward
- blasting – usually is not a core activity, with low equipment utilisation
- loading – can dictate productivity and influence production flexibility and grade control
- hauling – a major cost area; fluctuating fleet size (from year to year) may be a factor
- day works – if a project has a large day works component, then owner mining will be preferable
- ground conditions – uncertainty would make contracting out more risky
- water inflows – same as above.

It is in these areas that a cost, benefit and risk assessment is recommended, on a project-by-project basis.

ADVANTAGES AND DISADVANTAGES OF CONTRACT MINING

Whilst excellent contributions on this subject have been published by many authors, a selection of these will be referred to in this section.

Roche (1996) provided an excellent history of mine contracting, particularly in Australia, and observed a process of evolutionary change in the climate under which contract mining was conducted. This is depicted in Table 7.4.1, noting that in the 1960s mine contracting had yet to be introduced.

TABLE 7.4.1
A history of contract mining in Australia (after Roche, 1996, reproduced with permission).

	1970s	1980s	1990s	2000s
Relationship	Adversarial	Arm's length	Partnering	Alliances
Character	Ad hoc	Some continuity	Ongoing relations	Enduring relations
	Win-lose	Short-term advantage	Joint success seen as necessary	Trust and shared goals
Economic forces	Short-term profit	Operating efficiency	Economic efficiency	Long-term profit Realisation
Societal forces	Self interest	Some awareness of others	More awareness of others	Belonging

There is no doubt that the old adversarial days are gone, and that the decision to use contractors in the current business climate is primarily influenced by factors such as risk, balance sheet capacity and long-term profit performance.

Speaking of the future, Roche suggested that:

Over the decades there has been an evolutionary development of customer-supplier relationship that has significantly affected the way in which business is conducted.

In more recent times, equipment suppliers have entered more into this dimension with offers of performance guarantees and maintenance contracts with guaranteed mechanical availabilities. As a direct result, they have offered the mine owners an alternative partnership – either one where the operating risk is shared with the original equipment manufacturer (OEM) or, on the other hand, with the contractor. There is evidence to suggest that in some cases, the latter approach is being questioned by mine owners, particularly if long-term steady state production is anticipated and litigation risk by the contractor is a major issue.

Stephen Gillies, then managing director of Roche's parent Downer, commented on this subject (Anon, 2000(b)) as follows:

I am convinced of the merits of outsourcing based on mutually beneficial productivity gains and see this as the way forward in the mining and resource industries. Contract service providers make up a large proportion of the total cash costs of most mining operations. The mining contract is usually the largest single cost to be managed by a mining company, and is typically over 50% of cash operating costs. The mining industry does not have a good track record of maximising returns on its investment in mining equipment, in my view, largely because of a lack of focus on maintenance and equipment availability. Focus is one of the key attributes service providers can bring to the table, along with their pool of interchangeable equipment, equipment buying power and mobile workforce. The contractor only makes money on the last 20% of costs. Therefore there is no room for error. We have to know what we are doing or we go out of business.

Similar comments were made by Jukes *et al* (1992), who observed that at that time, an estimated 70 per cent of all mining operations in Western Australia were undertaken by contractors. The flexibility argument was exemplified with a number of examples from Thiess' experience. (Jukes was a former general manager with that contractor.) He listed the following:

- a temporary increase in production demand
- a short-term requirement to boost overburden movement
- a construction requirement, eg river diversion
- a major mechanical breakdown
- a structural failure of a pit wall
- infrastructure establishment.

Commenting on the use of outsourcing in general (Geddes, 2000) the author stated:

Most mining operations use some form of contracting ... to complement in-house skills. This may be as simple as the outsourcing of gardening services or as complex as handing over the raw geological data and requesting a price for a delivered product. In other words, it becomes not so much a question of 'Contractor' versus 'Owner Mining' but a question as to what degree outsourcing should be utilised.

Owner mining operations usually offer cash operating costs in the order of five to ten per cent less than contractor mining, but the contractor's margin is intended to compensate for both cash and non-cash costs and risk assumption. Geddes lists the following as being reflected in the contractor's margin:

- a return on capital invested
- compensation for off-site overhead and other costs
- a premium for risk assumption.

Geddes concluded:

... the relative cost differences between regimes tends to be less than ten per cent of contract value and the host of advantages and disadvantages can, for an individual mine site sometimes move this differential by up to 20 per cent. Therefore a good decision must be based on a structured approach balancing the quantitative/economic and the quantitative/semi-quantitative aspects.

Kirk (2000) lists five key issues to be taken into consideration when deciding owner mining options:

1. corporate issues
2. project-specific issues
3. operational considerations
4. costs
5. risk assessment.

Corporate issues would include availability of capital and access to the capital markets, whether or not the operating entity is a joint venture (in which the participants might have conflicting views), or a contractor might take equity in the project, or the organisation has a contract or owner mining culture.

Project specific issues would include mine life, whether the project is 'greenfields' or not, the variability of the mining rate, the availability of skilled operators, whether the mining is on the critical path, whether project financing requires greater confidence in the estimated mining costs, and whether any government incentives might influence decision making.

Operational issues would include whether the organisation has access to suitably skilled technical staff, whether the owners can match the contractor's generally longer work rosters (say four on, one off, versus two on, one off), whether the owner wants to take on the industrial relations risk, whether equipment flexibility is relevant (eg is a change of machine type necessary mid-project?), whether grade control is critical, whether mine plans will need to be altered at short notice, and finally, whether the focus of the operation needs to be profit based or quality based.

Cost issues would include the extent to which mining costs dictate total costs, what contractor's margin is considered to offset the commensurate risk transfer, whether too many functions would be duplicated, whether potential future savings, if any, might be shared, and finally, whether one large contract would be easier to manage than a number of smaller ones (such as fuel supply, tyres, maintenance, etc).

Risk issues would include (for owner mining) geological modelling, grade control, mine design, geotechnical stability, environmental and community issues, health, safety and marketing. With contract mining, the risk focus might shift towards equipment performance, production schedule adherence, latent conditions, force majeure and general litigation risk.

LITIGATION ISSUES

On this last point, it is arguable that litigation risk has two components:

1. the potential for the contractor to lodge claims and pursue them either in the courts or via the disputes procedure set out in the contract
2. the potential benefit to the owner of a 'hold harmless' indemnity clause in the contract, in the case where an employee of the contractor or any other contractor is injured.

Taking these two components in turn, the litigation risk can be significant. Over the last decade or more, many contractor claims have ranged from 20 per cent to as high as 50 per cent

of the contract value, with most being settled in the order of two to five per cent. If one adds the time and cost of this potential outcome to the contractor's original operating margin, it is easy to appreciate why litigation risk has been a major factor in the swing towards owner mining on some larger projects. All of the major contractors have been involved with major claims in recent times. Examples are included in Geddes (2000), where the author refers to Macmahon at Tarmoola, Thiess at Granny Smith and Leighton at Mt Keith. To this list may be added HWE Contracting at Marvel Loch, Fluor Daniel at Murrin Murrin and Roche at Greenbushes.

The second component relates to indemnity. If an owner and its contractor are involved in an accident on the owner's mine, and if there is an indemnity clause in the mining contract, then the owner will possibly not be liable for damages that might be awarded to a contractor employee injured at the mine in the said accident.¹ In a case in the north-west of Western Australia, the owner and contractor were both found to be responsible for an accident in which an employee was injured. Because of the indemnity clause, the contractor was liable for the entire damages bill, which was in the order of \$2 M. It was also shown in that case that the owner was in breach of the relevant mines regulations. In this instance, the indemnity saved the owner its contributory component, which, by way of illustration, on a 50:50 basis would have amounted to \$1 M.

'ARM'S LENGTH' AND 'GOOD FAITH' CLAUSES

For further comment on some legal issues Komesaroff (2000) gives an interpretation of the meaning of 'arm's length' contracts and 'good faith' clauses. The latter was used at Granny Smith and was found by Templeman J to have been breached by the contractor. The paper is useful in that it explains in simple language that, in a normal schedule of rates contract, the contractor is at arm's length, that is, he has no fiduciary responsibility to the principal. In other words, as long as it complies with the terms of the contract, it can do whatever might be in its best interests. This may lead, in some cases, to an adversarial contractual climate.

With a good faith clause (carefully worded), however, this is no longer the case. In the Granny Smith case, the court accepted the legitimacy of this type of clause, thus paving the way for a more open, cost sharing style of contract. Komesaroff makes the following interesting points:

- contracts explicitly purporting to be partnering agreements or contracts that contain 'good faith' clauses are valid and will be recognised by the law as functional and effective
- a good faith clause will be, in principle, effective and will be treated by the law as such
- the concept of good faith actually consists of, amongst other things, goodwill on the part of both parties, reasonable cooperation on the part of both parties and an obligation of the parties to deal and act honestly and fairly with each other.

GEOGRAPHICAL FACTORS

Geographical factors may play a role in the choice of the preferred mode of operation. For example, a new player in an established field might be influenced by the manner in which things are done on that field. Alternatively, the new player might not have the mining expertise freely available in the area in which they have newly invested.

For example, AngloGold used contract mining at most of their Australian operations as they became established in this country in 2000. They used Roche at Tanami, HWE

1. Notwithstanding this, mine owners must be aware that it is not legally possible to 'contract out' a statutory responsibility, such as a general duty of care.

Contracting at Boddington and Macmahon at Pine Creek. According to Robin George, Anglo's then executive director exploration and mining (Bell, 2000):

Most of Anglo's expertise in South Africa is in deep underground operations. So I don't think they'd look at open pit mining as a core competence, whereas it is a core competence of mining contractors.

Later, a similar pattern emerged with the acquisition of the WMC gold assets at St Ives by South African-based Gold Fields Ltd. A substantial open pit mining contract has been awarded there to Leighton Contracting, reported to be worth \$300 M.

Placer Pacific Ltd (PPL) was a geographic business unit of Placer Dome Inc (PDG), a large international gold producer. In the late 1990s, PDG was operating in six countries around the world, in Australia, Chile, Venezuela, Papua New Guinea, Canada and USA. The company operated at that time 14 mines globally, of which approximately 11 were open cut operations. Many of those operations employed contractors to provide routine services such as catering, but only two used mining contractors. The reasons are interesting and may be found in Hills (1997). Hills refers to the obvious issues of core competencies, expertise, financial strength, economics, risk spreading and immediacy before listing the reasons why owner mining or contracting were adopted at each of the case study sites listed in the paper. These may be summarised below:

- Misima: owner mining; ten-year mine life
- Bald Hill: contracting; short mine life
- Granny Smith: contracting; short mine life, higher risk initially
- Osborne: contract open pit; short life 16 Mt; owner underground; core competency
- Kidston: owner mining; substantial mine life and scale of operations.

Hill concluded that the major decision drivers for Placer included the issues of core competence, relative risk and finally timing constraints.

FINANCING ISSUES

It is often said (Roche, 1996) that contract mining obviates the need for a mine owner to capitalise its primary mining fleet. This is easy to understand when one considers that a mining fleet for a mid-sized open pit mine might cost anywhere from \$50 to \$100 M, or more.

In more recent times, however, this is not the case, as upfront capital can be overcome by fleet leasing arrangements. The two most common forms are operating leases and capital leases.

Operating leases

Operating leases are typified by the mine owner leasing the fleet from the equipment supplier. Ownership (and therefore responsibility for insurance) remains with the supplier and the equipment's residual value at the end of the lease is vested in the supplier. The lease payments may be treated as an operating expense by the mine owner. Hence, upfront capital costs are avoided.

In many cases, operating leases are preferred and they are common in Australasia. They can, however, have the drawback that the supplier may look for security (in the form of a parent guarantee) in an area with perceived 'country risk'. This was the case with a project recently proposed for Papua New Guinea.

Capital leases

A capital lease, on the other hand, operates like a hire purchase agreement. The mine owner makes staged payments as before, but at the end of the term may own the fleet outright or sell it back to the supplier for the residual value. The difference is that the mine owner pays for insurance and may treat the lease payments as a capital expense.

Either way, the burden of upfront capital is avoided. The explanation is a little oversimplified, as in practice, the financing is more complex, often involving intermediary lending institutions, but the end result is the same. From country to country, the form of leasing arrangement that is adopted may be influenced by the prevailing taxation arrangements, which may in turn affect the lease term.

OWNER MINING CASE STUDIES

A number of owner mining studies have been completed by mining companies in Australasia and elsewhere in recent years. The results of some of these were reported in Dunlop (2002) and are summarised in Table 7.4.2.

TABLE 7.4.2
Case studies – owner mining cost savings.

Mine	Savings (%)	Status
KCGM	17	Achieved
Lihir	25	Achieved
Tarmoola	10	Achieved
Cadia	14	Achieved
Ernest Henry	12	Achieved
Wandoo	10	Planned
Ravensthorpe	11	Planned
Macraes	7.5	Planned
Average	14	

For the batch of studies referred to, the average owner mining cost saving (either achieved or planned) was 14 per cent, reflecting the perceived contractor's margin and risk premium.

Notwithstanding this, Sunrise Dam was not the only significant operation to continue to embrace the contract mining option. A list of major earthmoving contracts in Australasia usually appears each year in June (Bell, 2000) from which (at that point in time) the following were significant: Yandi, Century, Marvel Loch, Callie, Nifty, Granites, Milmerran, Mt Keith, St Ives, German Creek, Latrobe Valley, Collinsville, Mt Burton, Mt Owen and Newlands. Since then, some of these have moved to owner mining as well.

It is also relevant to note that St Barbara Mines, a gold miner operating out of Cue, Western Australia, moved from owner mining to contract mining at the time the study results appeared. Whilst this may seem, in the light of Table 7.4.2, to be a move in reverse of the then prevailing trend, it has a simple explanation. The group's activities were then more diverse and its open pits of a shorter operating life than was previously the case when its operations were centred at the Bluebird pit. As a result, the flexibility of contract mining had more economic appeal. Owner mining studies were still undertaken, however, so as to benchmark the contract mining tendered prices.

There can be little doubt that the original preference for owner mining established in the Pilbara iron ore mines in the late 1960s is returning. The reasons are many, but not least amongst them are the issues of cost, mine life and mining risk assumption. Perhaps the most striking recent example is the sale of contracting business HWE Contracting to BHP Billiton as part of that company's move to owner mining operations throughout its Pilbara operations. It is evident that more operations featuring a steady state and relatively long mine life will be obliged to examine or re-examine the owner mining option as their continuing improvement strategies dictate.

7.4.2 Geotechnical considerations

Current mining industry practice in Australia requires that mine managers ensure geotechnical issues are properly considered at key stages in the design and operation of the mine. A geotechnical management plan must be developed and implemented and sufficient resources should be allocated to allow the plan to be followed throughout the life of the operation. These requirements are essential to achieving the full economic potential of the project, and to proper management of geotechnical issues and hazards.

Historically, many mining projects have failed economically, or technically, or have experienced disasters involving multiple fatalities, through inadequate understanding of geotechnical issues. Well-known mining disasters include the Coalbrook North Colliery room and pillar workings collapse (1960), the Mufulira tailings inrush (1970), the Northparkes airblast (1999) and the Crandall Canyon coal mine collapse (2007).

Details of some of these are provided in Brady and Brown (2004), and in the listed references.

Table 7.4.3 lists some examples of major mine accidents and mining projects that failed, or seriously underperformed, where geotechnical issues were major contributing factors.

TABLE 7.4.3
Examples of accidents or failures attributable to geotechnical issues.

Mine	Major issue	Date	Fatalities	Economic loss	Reference
Coalbrook Colliery, South Africa	Sudden collapse of about 3 km ² of room and pillar workings	21 January 1960	437	Not available	Brady and Brown, 2006
Mufulira, Zambia	Inrush of 450 000 m ³ of tailings through the cave column	25 September 1970	89	Sterilisation of 4 Mt of developed ore; production reduced by 70 - 90% for several years	Brady and Brown, 2006
Asfordby, United Kingdom	Unexpectedly strong hanging wall did not cave causing adverse face conditions	1997		Mine closure after three years. Write-off of about £350 M	Mining Magazine, October 1997
Northparkes, Australia	Sudden caving of about 15 Mt resulting in a devastating airblast	24 November 1999	4		Brady and Brown, 2006
Goldex, Canada	Unexpected subsidence connection with surface aquifers	2011		Mine closure after three years. Write-off of US\$260 M	Topf, 2011
Crandall Canyon, USA	Major collapse of barrier pillar, accompanied by a Richter 3.9 seismic event	6 and 16 August 2007	6 + 3 rescuers	Mine closure	Kennedy, 2008

In major disasters, particularly where loss of life has occurred, the contributing factors are usually closely and methodically examined in public inquiries, and are therefore well documented. However, in ongoing operations, the effects of inadequate geotechnical input or poor management of geotechnical issues are usually more subtle, and often simply result in project underperformance.

For example, higher than expected dilution, lower head grades, lower resource recovery and higher support costs all lead to reduced stakeholder returns. Mine life is also often shortened. These issues are rarely examined in public, but cost the industry and investors many millions of dollars.

LEGISLATIVE REQUIREMENTS

Each of the Australian states and territories has its own mining regulations. In most of these, the discussion of management of geotechnical issues and hazards is very general.

There are plans to harmonise workplace safety laws under a national 'Work Health and Safety Act' (2011) (dealt with in more detail in section 7.1 of this chapter), which includes guidelines on various aspects of managing geotechnical issues in mining operations. However, these have only been accepted in the Northern Territory, Australian Capital Territory, Queensland and New South Wales. As at March 2012, the other states have rejected or deferred adopting the act.

In Western Australia, the Department of Minerals and Energy (DME) has issued guidelines for the management of geotechnical issues in both underground and open pit operations. These are fairly comprehensive and carefully considered, and as such have been adopted as industry best practice in other Australian states and territories. They describe what is expected of mine managers in the context of managing geotechnical hazards and issues.

The guidelines were developed to assist in interpreting and complying with the regulations covering geotechnical aspects of mining operations.

The relevant sections of Western Australian (WA) mining regulations are represented below. Obviously these are only applicable to the Western Australian mining industry. Nonetheless, they provide guidance that is generally applicable on the main geotechnical issues that should be considered and adequately managed in underground and open pit mines respectively.

It is also noted that the geotechnical guidelines that accompany the proposed harmonised Work Health and Safety Act (WHS Act) appear to be largely based on the WA guidelines. If the WHS Act is eventually adopted nationally, then the WA guidelines will effectively become the national standard.

Geotechnical considerations (underground mines)

Regulation 10.28

1. The principal employer at, and the manager of, an underground mine must ensure that geotechnical aspects are adequately considered in relation to the design, operation and abandonment of the mine.
2. The principal employer at, and the manager of, an underground mine must ensure that the following things are done in relation to workplaces, travel-ways and installations underground in the mine:
 - a. due consideration is given to local geological structure and its influence on rock stability

- b. rock damage at the excavation perimeter due to blasting is minimised by careful drilling and charging
 - c. due consideration is given to the size and geometry of openings
 - d. appropriate equipment and procedures are used for scaling
 - e. appropriate measures are taken to ensure the proper design, installation and quality control of rock support and reinforcement
 - f. the installation of ground support is timed to take into account rock conditions.
3. The principal employer at, and the manager of, an underground mine must ensure that the following things are done in relation to all development openings and stoping systems underground in the mine:
- a. geotechnical data (including monitoring of openings when appropriate) is systematically collected, analysed and interpreted
 - b. appropriate stope and pillar dimensions are determined
 - c. rationale for sequencing stope extraction and filling (if appropriate) is determined
 - d. there is adequate design, control and monitoring of production blasts
 - e. rock support and reinforcement are adequately designed and installed.

Geotechnical considerations (open pit mines)

Regulation 13.8.

- 1. The principal employer at, and the manager of, a mine must ensure that geotechnical aspects are adequately considered in relation to the design, operation abandonment of quarry operations.
- 2. Each responsible person at a mine must ensure that the following measures are taken in relation to ground control in the quarry:
 - a. adequate consideration is given to local geological structure and its influence on wall stability
 - b. adequate consideration is given to shear strength of the rock mass and its geological structure
 - c. a proper analysis is carried out of rainwater inflow, surface drainage pattern, groundwater regime and mine dewatering procedures and their influence on wall stability over time
 - d. where necessary, appropriate designs of rock reinforcement are applied and used, and the quality of installation is verified
 - e. analysis is carried out of open pit wall stability for the projected geometry of the pit
 - f. appropriate drilling and blasting procedures are used to develop final walls
 - g. appropriate methods of open pit wall monitoring are used over a period of time to determine wall stability conditions.
- 3. Each responsible person at a mine must ensure that appropriate precautions are taken and written safe working procedures are followed if open pits are excavated through abandoned underground workings, or in close proximity to current underground workings.

GEOTECHNICAL MANAGEMENT PLANS

To meet the above requirements, it is good practice to develop a geotechnical management plan. These are also referred to as a ground control management plan (GCMP).

The plan describes all the geotechnical activities and inputs required in the planning, design and operation of the mine. The scope of the plan, and the resources required to implement it, will reflect the scale and complexity of the operation.

The accountabilities and responsibilities of all key personnel, including the manager, are set out in the plan. There may be specific experience and qualifications required for some of the appointments. Management responsibilities typically include ensuring that:

- Management systems and work practices comply with the requirements of all applicable legislation.
- Suitably qualified and experienced persons are formally appointed to the key technical and operating positions involved in geotechnical activities.
- Adequate resources are available to allow the GCMP to be implemented and complied with.
- Ground control procedures are reviewed regularly and enhanced, with workforce involvement where appropriate.
- Audit, review and quality assurance programs are carried out regularly and documented.
- An external audit of the GCMP is conducted at suitable intervals to ensure industry best practices are applied. The audit will also look specifically at longer-term issues and hazards that could be overlooked by internal review processes, as a result of their shorter-term focus.

Hawley *et al* (2009) present a thorough, detailed discussion on the management of open pit geotechnical issues. This includes a section on the content of ground control management plans. They suggest that a typical ground control management plan should cover the topics presented in Table 7.4.4.

While the topics in Table 7.4.4 are specifically for the management of open pit geotechnical issues, the requirements of an underground mine can be considered to be very similar.

7.5 EQUIPMENT RELIABILITY IMPROVEMENT AND MAINTENANCE

Achieving a reliable plant is far more complex than just maintaining a plant. Sources of poor reliability include how the plant is designed, modified, commissioned and operated; the quality of parts; personnel skills; as well as how effectively the plant is maintained. Most organisations have advanced from maintenance effectiveness to a more holistic plant reliability focus. Failure to understand this will mean you may be 20 years behind the times in an industry often (wrongly) accused of not employing cutting-edge practices.

Fixing equipment-related problems after they occur gives an immediate reward of personal satisfaction: it builds reputations and provides an easy and obvious method for employee recognition. Not having problems is far more difficult to evaluate, takes sustained discipline and does not have the immediate rewards of self-satisfaction and recognition. This paradox is central to evolving a proactive culture that values reliability.

A manager's actions support and reinforce behaviours. If managers demonstrably value the heroic efforts to get a broken plant operating but do not do the same for the more mundane discipline that ensures problems are not experienced, then they are inadvertently supporting a breakdown mentality and reactive culture. If managers do not display an interest in routine KPI reviews and gap closure plans, then they are not promoting a proactive

TABLE 7.4.4
Typical content of ground control management plans (Hawley *et al*, 2009^a).

Information	Typical table of contents
- Legislative requirements - Hazard identification and risk management process - Basic geotechnical domain model based on geological and geotechnical history of the operation and mining lease - Regional and structural geology site characterisation - Rock mass characterisation - Groundwater distribution - Stress and seismicity - Ground control management plan and related standard operating procedures - Data collection - Modelling, analysis and pit slope and ground support design - Excavation and performance monitoring - Mitigation options and remedial measures - Inspection and monitoring program - Trigger action response plans - Duties and responsibilities - Training requirements - Communication - Audit, review and feedback process	- Introduction - objective - scope - definitions - references - mining environment description and characteristics - relevant mine history - Identified hazards - Control procedures - risk management system - identification of high-risk environments - communication protocols - permits - sampling and monitoring - accepted movement threshold values - formalised controls - Roles and responsibilities - Resources required - training - communication - review and audits - Trigger action response plans - Communication - Training - Corrective actions - audit (internal/external) or reviews - verbal communications, incident reports - non-conformance reporting - Review/audit - not exceeding 12 months, or when a significant change occurs - Document control - Records - safety management plans - hazard management plans - trigger action response plans (TARPs) - standard operating procedures (SOPs)

a. Reproduced from *Guidelines for Open Pit Slope Design* (Hawley *et al*, 2009) with kind permission from CSIRO Publishing. This volume is available from <http://www.publish.csiro.au/pid/6108.htm>

culture of learning and continuous improvement. Managers need to set their personnel up for success, and success means a reliable plant.

7.5.1 Maintenance philosophies

There is a strong linkage between reliability, safety, costs and output. It is well recognised that there is a strong linkage between good safety performance and good reliability. Some industry data shows a statistical correlation coefficient of greater than 0.9. This is not only because a planned job means that decisions and risks can be assessed with forethought and confidence but also, there is less personnel exposure. It is obvious that less intervention on equipment gives personnel less exposure to risks. It is also true that the sustained organisational discipline required across all roles for excellent safety performance is similar, if not identical, to the discipline and dedication required to operate equipment with care and maintain equipment with precision. We correctly expend a lot of effort to proactively prevent risks and actions that could harm people. Exceptional reliability requires a lot of effort to proactively identify risks and actions that can lead to losses. It is a simple parallel but seldom fully endorsed and energised by an organisation.

It is generally accepted that doing work on equipment in a planned fashion is quicker and more cost effective than doing reactive corrective work. Multiples of two to five times are often cited. It should also be mentioned that the initial goal should not be maintenance cost cutting as this will be an outcome in terms of cost per unit of production. The economic leverage is usually greater in the area of 'first-pass quality, production increase' when moving from a breakdown maintenance regime. There are also many intangible benefits, for example, employee morale and the market reputation of the organisation. Effective reliability reduces frustration and can turn your repairers back into 'craftpersons'.

Improving reliability is not a 'maintenance only' function. It involves a team commitment to address the sources of defects that lead to losses. Inherently then, for success it is necessary that the level within the organisational structure responsible for the operations section and the maintenance section (and the stores, transport and projects section come to that) play a leadership role and set their employees up for success. There must be recognisable support at this level (Moore, 2004).

ADOPTING A DEFECT ELIMINATION FOCUS – HISTORICAL DATA DRIVEN (REACTIVE APPROACH)

While it is better to not have unforeseen equipment problems in the first place, starting this discussion at the point where disruption has already occurred may be of value.

Defects are conditions or actions that can, or have, manifested themselves as losses. A defect elimination focus requires organisational-wide leadership in order to remove defects at their sources. Defects lead to eventual production losses and thus rob the operation of production capacity it may have depended upon. Eliminating defects taps into the 'hidden plant capacity' that has already been paid for, but that cannot currently be utilised.

Understanding the root causes of lost capacity is a very effective way to increase profitability. Your fixed production costs are already covered by your existing capacity, therefore each extra tonne has a potential windfall profit margin. This is particularly the case if your targeted production budget is based on your historical production, with its already inbuilt losses. Making more of the losses visible is why loss accounting systems compare actual production to a maximum demonstrated or sustainable rate rather than a budgeted rate. This gives a larger gap between actual and realistic (demonstrated) performance. The explanations analysed for this comparatively larger production shortfall lead to greater

problem understanding and more potential improvement, by using tools like root cause analysis. Plant bottlenecks are identified and progressively removed. By recording first-pass reasons for the losses the operators also provide their own real-time feedback by an initial formal reflection on plant operation. This offers a double benefit.

Production loss accounting systems (such as Uptime / Asset Utilisation / Overall Equipment Effectiveness), are generally the tools used to understand the historical issues that erode profitability and increase potential, but they can ignore unused plant capacity. Since the reasons for your production losses cover many role accountabilities, these tools should be backed up by a team-based approach to cause analysis and resolution. Without these two enablers of a loss accounting system and a robust root cause analysis tool, historical losses will continue to be problems.

Whilst these systems are fundamental, they are also somewhat limited in actually achieving the desired level of reliability. They record actual historical issues and hence are inherently reactive in nature. It is necessary to adopt both a reactive and proactive approach to defect elimination to have world-class production reliability success.

ADOPTING A DEFECT ELIMINATION FOCUS – A PROACTIVE APPROACH

The proactive approach is complementary to the above and additionally requires an organisational focus on the elimination of defects at their source. This also requires a team approach, with all roles operating cooperatively with their focus on potential loss-causing conditions and actions within their control.

This approach also highlights the difference between asset management and maintenance. The latter is a subset of the first. Asset management covers the equipment life cycle commencing at design through to asset disposal. Eliminating defects before they manifest themselves as losses is the key requirement. Defect sources are potentially derived from design, equipment specification, poor/subordinate technical tender evaluations to price, poor transportation, storage, commissioning, management system preparedness and maintenance activity identification, poor spares holdings, information availability, poor commissioning and other similar operational readiness related issues. Throughout the industry there is a strengthening effort being invested in 'operational readiness' as a specific subject to ensure quick ramp-up to full and sustainably reliable production.

The project culture is inherently a key driver for operational readiness in major capital works. The three required outcomes for a project are cost, time and quality. The first two are easy to measure at the time of commissioning and usually what the project completion measures (and personnel bonuses) are based upon. The quality aspect is far more difficult to access unless there are appropriate checklists and hold points² built into the project management discipline. The project quality attribute can have a huge impact on long-term equipment reliability and operability.

Operations and maintenance department involvement in design reviews, commissioning, training, systems readiness and acceptance testing are commonly used, but may not be effective if there are conflicting interpretations as to the trade-offs inevitable in achieving the tripartite project goals.

After commissioning, there are the potential sources for defects associated with not operating with care and within design capabilities, maintaining poorly and without precision, poor training, parts, lubrication, alignment, etc.

2. These were also referred to in Chapter 6 as 'toll gates'.

Organisation structures and systems are enablers. The former being more dependent on the maturity and discipline in the management processes. The maintenance structure is generally either centralised reporting to an asset management manager, or decentralised reporting directly to the operations customers in some form.

Centralised control of the core maintenance disciplines, such as planning and scheduling, reliability engineering and technical support is advisable when the organisational discipline and maintenance management processes are not mature, or not well accepted and followed. On occasions the wrong reasons, such as the operations customers wanting control and accountability for maintenance, are used for decentralising these key aspects. The maintenance and reliability business process components generally require specific technical skills and are interwoven in a specific order. They require concerted discipline to ensure no component breaks down in the chain of actions and accountabilities. If any component is executed poorly all subsequent activities and the final outcome of reliable equipment will suffer. Before decentralising your maintenance department, an evaluation of the maintenance business process maturity, and its adoption, should be done. Supporting management systems need to be functional, data structures defined and up-to-date and monitored via KPIs, to ensure the correct discipline is adopted. As an example, most companies use the KPIs for the important maintenance work management cycle of 'intended schedule completion percentage', 'percentage of total work done that was scheduled', 'preventive maintenance activities percentage complete' as core indicators; as they work in combination, the first two are commonly plotted on a two axis graph, sometimes with a red and a green zone. Mine managers can greatly assist defect elimination within this business process by expecting weekly team reviews of at least these fundamentals. A remarkably common mistake is to drive for KPI value increases instead of demanding a proper gap analysis of the KPI result. If the causes are identified and corrected, the KPI level will look after itself. This is supported by routine effective and simple questioning from upper management about the identified corrective actions rather than handing out brickbats for the result. 'To have a bad KPI result is forgivable, to not understand the reason why is a crime.'

It is recommend that managers take the time to promote this by routinely asking some brief questions that will show that they value defect elimination, and will therefore help to support the overall equipment reliability philosophy.

AN EQUIPMENT RISK PERSPECTIVE – ANOTHER SLANT

There is direct support for the above defect elimination focus in any conversation on risk. The discussion below may help to identify the potential solutions to improve the production reliability goal.

- *Historical defects that have led to losses:* (refer to above) use uptime or other loss recording and prioritising (ie 80/20 rule, where 80 per cent of the effects come from 20 per cent of the causes) systems and then apply root cause analysis to eliminate these. This requires workforce participation and leads to improvements in all aspects where defects can be initiated. Inherently, though, this has a reactive basis.
- *Known equipment defects that have not yet led to failure and loss:* monitor condition. Managers can risk rank the known defects by considering consequences (C), the time to mature for the final failure (a likelihood measure, L) and the detectability (D) of the defect's progression towards failure, ie risk index = $C \times L \times D$. This resulting risk index can be used to allow a priority-based focus on the critical equipment faults that the team can identify. Broad personnel involvement is obviously the key to tap into the signs of defects being present, not just from technical condition monitoring techniques. This effort is somewhat a mixture

of reactive (as the defect is known and present), and proactive (as final failure may not yet have occurred). Once the risk is established, it should become clearer where to expend effort on eliminating known defects. This process also identifies where contingency and mitigation plans are required to limit losses, if the failure were to occur prior to correction. Condition monitoring improvements and where current equipment maintenance procedures are deficient may also be identified and corrected. If this plant risk assessment includes the cost for the corrective action, the output can also be a more justifiable budget allocation mechanism for major maintenance and sustaining capital.

- *Equipment with currently undetected defects:* these are sources of future breakdowns, so the core issue is how to detect them. Workforce engagement (a common theme in all items listed to date) and improving condition monitoring practices are obvious solutions. Condition monitoring includes the specialty techniques that interest non-destructive testing and reliability engineers. It also critically includes listening to and gathering feedback from the operators, based on their equipment performance monitoring and routine observations. The maintainers and lubrication technicians who routinely visit equipment can also be of great help. Progressive mineral processing companies adopt some lean manufacturing techniques³ such as '5S' (Gapp, Fisher and Kobayashi, 2008) and 'deep clean' activities to assist.
- *Potential defects, not currently present:* this consideration is based on a future, proactive view of preventing defects from even occurring. Some aspects have already been overviewed in the section above on operational readiness. An obvious addition is the requirement for a robust and disciplined change management / modification control process that covers projects, maintenance, operations, procurement and stores, in order to prevent defects from being introduced. Continuous improvements to the planned maintenance activities based on expected failure modes and historical performance can prevent defects from occurring also. Some of the techniques used are failure Modes Effects Analysis, Reliability Centred Maintenance and Preventive Maintenance Optimisation (Moore, 2007).

SOME ENABLERS

The importance of suitable upper management support, cross-functional teams, organisational structures and systems has been emphasised. It follows inherently that achieving reliable operations and equipment is not solely the regime of the maintenance section. There are some other issues that should be considered for the transformation from a reactive, breakdown maintenance system.

The lean manufacturing concept of the 'visual workplace', which has the natural work-team evaluating their past 24 hours with KPIs relevant to them, and in a simple red and green visual format, is excellent for crew engagement. The issues are identified and tracked until correction. Where this has been appropriately installed, the workforce commonly reports feeling empowered. This is an important motivator for exercising precision and care in order to perpetuate reliability. This meeting can also be used as a verification step for the production gaps over the last 24 hours before they are uploaded into the loss accounting system.

Many companies have multiple sites and possibly functional expertise for asset management in a head office. Not many companies, however, have particularly well

3. Lean manufacturing, lean enterprise, or lean production, often simply, 'lean', is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination. Working from the perspective of the customer who consumes a product or service, 'value' is defined as any action or process that a customer would be willing to pay for. Essentially, lean is centred on preserving value with less work. Lean manufacturing is a management philosophy derived mostly from the Toyota Production System (TPS) (hence the term Toyotism is also prevalent) and identified as 'Lean' only in the 1990s.

harnessed this matrix structure for mutual assistance, group learning, governance and uniformly adopting best practices. The formation of a matrix structure, working across the pyramidal hierarchy of the sites structures, can be confronting, but is necessary in some form to gain functional excellence where there is inherently no structural authority.

With careful design and alignment where the business planning process goals cascade down to interdependent personal objectives, this matrix structure can draw off the collective intelligence and experience from a functional slice across the organisation. The exercise to achieve this effective functional matrix for asset management is not trivial in terms of organisational maturity and management trust. It is commonly not done well, and a significant opportunity can potentially be lost for organisations with divisional or multiple site formats. Transparency, sponsorship, involvement and cascading goals are essential to build this relationship. The numbers of personnel representing head office functional expertise can be quite small when this matrix structure is operating effectively, as the 'virtual team' is vast.

In brief, these cross-organisation functional linkages and teams have the fundamental goals of:

- Determining and addressing common, possibly organisation-wide, site customer needs.
- Identifying opportunities for mutual assistance amongst the sites that they can work together to resolve, thereby overcoming the necessity to learn the same lessons at each site, repeatedly.
- Benefitting from the knowledge and expertise of a group of functional peers for strategic direction.
- Supporting and adopting consistent practices, standards and processes. (This is necessary to get the most from a common enterprise management tool such as SAP for example.)
- Identifying and sponsoring short-term, cross-site improvement focus teams on required topics. These could be for either equipment or process improvement projects.
- Providing a cascading linkage from any operational leadership team comprised of site and functional general managers, and the site-based asset management improvement teams.

In doing the above, it is possible to provide an effective functionally-focused team across the organisation that supports both the short- and long-term organisation and site goals.

PROMOTING RELIABILITY AS A CULTURAL CHANGE

There is an obvious need to provide suitable skills training to support the specific equipment and management processes both in operations and maintenance to ensure defects are not introduced through poor work practices. There are also a few courses available that engender a suitable reliability culture within an organisation. There are notable experts who can awaken an organisation to the fact that, as with safety, excellence in reliability requires an organisation-wide focus. There are also organisations that can assist with cascading these concepts through the management hierarchy to promote this necessary reliability culture. Characteristically these workshops take from one half day to two days. Since the goal is to embed a foundation of reliability culture across the various work teams, it requires peak authority for support. The divisional manager/general manager level should participate in the initial workshops, then help the culture to permeate to the operations, maintenance, stores and projects natural work teams on-site.

THE BASICS SUMMARISED

Operate with consistency and care; maintain with precision. There are also other fundamental issues relating to equipment maintenance that must be demanded, as outlined below.

Equipment cleanliness: is necessary to identify faults easily, engender ownership and improve performance. Contamination and heat build-up can lead to poor reliability.

Lubrication: standards, correct selection and application, filtered desiccant breathers, sampling points, clean supply, storage and transport are all critical. Some sites have found that new lubricants, as received directly from the suppliers, exceeded their site's contamination guidelines. Many sites do an excellent job of lubricant contamination all by themselves. Even small levels of contamination can halve equipment life.

Alignment and balancing: should be standardised and checked. Generally, the more precise the better will be the longevity. The effort should be balanced by the consequences of the equipment failure.

Securing: means ensuring that things remain bolted down. Use calibrated torquing of critical fasteners.

Operate plant consistently between shifts, and within the equipment capabilities. Some initial equipment issues can lead to an unstable and self-reinforcing boom and bust cycle, whereas stable operation may give better overall output. Take the long-term view for achieving higher levels of consistent operation in a planned domain. The equipment will always demand the maintenance it needs, and neglecting maintenance is a false long-term economy. Consider also the impact of removing bottlenecks and the reduction of buffer stocks between processes in terms of the equipment production criticality and its sensitivity to defects.

Don't waste your fixed plant shutdowns: it is common to see known defects not being given adequate resources for their correction when shutdowns are frequent and routine, only to find that the reliability is not fundamentally improving when you need the plant for production. The defects remain unaddressed. The extreme is where the bottleneck of the plant changes (moves from the mine to the processing plant for example) often foreseeably due to ore type, mining improvements, etc, and the opportunity to improve the new processing bottleneck has been lost over the preceding months. Often the limited budget is used as the reason for inactivity. A total cost view, including the future production loss, would show that it is usually better to eliminate the risk from known problems in the critical processing equipment when the opportunity arises.

A CASE STUDY

A well-known example of a multinational manufacturing organisation is instructive. It reveals that they found three key focus components for a plant uptime improvement of 15 per cent (full uptime is first-pass quality production at maximum sustainable rate).

The three core components were:

1. *Equipment condition monitoring:* ie knowing what the equipment needs and when it is required (see risk above). Some industry data indicates that the majority of all equipment failure modes are represented by a constant probability of failure. Where this is the case it is not totally effective to use a constant time basis for maintenance activities. This underscores the importance of effective condition monitoring to understand any progression towards functional failure.
2. *Disciplined and robust planning and scheduling:* ie equipment, people, skills, preparation, parts coming together with the right quality and quantity at the right time.
3. *Defect elimination at the source:* ie eliminating items, existing or future, that will cause losses (refer above).

When you get rid of the technical labels, these three focus areas should make common sense, ie 'know what we have to do, make sure we do it and eliminate potential sources of loss.' The detail in the work behind this simplicity is where the expertise comes in.

As an example, take planning and scheduling; in order to do this effectively, a 'maintenance work management process' is required. There are a variety of essential precursors to effective planning and scheduling. Even after the planning and scheduling stage, the execution needs to be of high quality, requiring training, quality assurance, recording outcomes and an evaluation and improvement processes. In order to complete effective planning and scheduling the equipment register and bill of materials listings need to be complete and of good quality. Spare parts holdings and logistics, labour, tools and equipment need to be effective. Approval and reviewing type roles need definition. A pact between the users and maintainers regarding release of equipment and duration of the work needs agreement.

To achieve success the individual issues requiring resolution are many, requiring interfaces with multiple partners along the chain of actions. In total it is quite a complex interconnected process unless a discipline is established. For example, establishing effective preventive maintenance activities involves selecting the appropriate maintenance tactics that address the specific failure modes from each component within each piece of equipment, high levels of completion of these tasks and a continuous improvement loop when the current tactics are found wanting. There is considerable sustained effort in ensuring that this process and discipline is consistently applied. Each element of the maintenance work management business process has similar levels of detail and specialist skills required to be effective.

So, the key to reliable production is exercising long-term discipline, commitment, common sense, providing suitable enablers and supporting the effort that is not as easily identified as repairing breakdowns. It needs recognition that preventing issues from occurring is ultimately more important than perfecting a reactive culture than can fix breakdowns quickly. Both are initially important but if the manager is addressing the correct issues, one will be required less.

CONCLUSION

While not having problems may be less exciting than quickly getting back on one's feet after being knocked down, it should be rewarded and valued so that it finally results in a site and organisation that enjoys reliable production. One of the management challenges discussed is to demonstrably value non-events, that is, the dedication and effort expended in not having issues.

Addressing the issues mentioned above and upper management asking a few questions to show that they are interested and value the culture associated with proactive defect elimination, will help tap into your hidden plant by improving reliability. Remember that if you do not take control, or alternatively spend time inappropriately focusing on cutting maintenance costs as your initial strategy, 'the equipment will always demand the maintenance it needs'.

7.6 MATERIALS MANAGEMENT

7.6.1 Materials management philosophies

It is a frequent misconception that because the supply function is not a primary revenue-earning agency in most mining companies, it should be afforded a lesser priority for

assignment of resources and involvement in the organisation's strategic planning. It is too easy to disregard, in the search for more tonnes moved or metres drilled, that the supply function is usually responsible for the actual execution of up to 80 - 90 per cent of the all the organisation's non-employee wages and salaries spend. If the supply function is the target for staff economising or the repository for the undesirable, incapable or the incompetent, bear in mind that it is the function responsible for the effective spending of most of the money and the efficient management of its proceeds.

The recognition of the importance of the supply function in managing the non-employee cost base is increasingly being reflected in both national and multi-national organisations where the deployment of equipment and stores is geographically distributed, supply delivery chains are long, and where in remote regions or third-world communities the supplier market is complex or constrained.

Clearly the supply function needs to be scaled to match the size and nature of the operation it supports and it doesn't necessarily need to be fully deployed on-site. There are some attributes, however, that are common to most organisations that have extended beyond a single mine site. The challenge for operational management is to recognise the point at which the small supply supporting team giving almost personalised service to operations staff at a very low level of productivity, using conveniently located suppliers and with little capital exposure, needs to be replaced with more systematic and deliberate procurement and inventory management. Failure to act will almost guarantee the circumstances frequently seen in expanding mining companies where the entrenched customer behaviour reflects poor planning and forecasting, and where there is little or no volume leverage due to poor customer discipline and the supply staff are so conditioned to personalised service they have no capacity and little ability to improve. There is typically no negotiated leveraged procurement culture, cost-effective but constrained and consolidated supply chain management or optimised inventory levels.

There is clear evidence both in Australia and overseas where mining companies have been able to facilitate considerable production growth without a parallel growth in the costs of the supply function. Efficiencies can be realised by investing in personnel skills and capabilities and enterprise resource management tools to increase the productivity of the existing resource base by up to 400 per cent while significantly constraining or reducing the procurement costs of the required equipment and consumables, depending on global markets at the time. The investment in supply compared to the cost of a single large underground or surface loader or truck is realistically small, but is worthy of considered thought.

7.6.2 The supply function

Terminology commonly used to describe the supply function with variable accuracy include purchasing, procurement, stores, inventory, logistics, supply chain management and so on. However, for the purposes of this discussion, the supply function is defined as comprising the following basic activities.

PROCUREMENT

In its simplest form the procurement process is initially triggered by an end user requirement being registered in the supply system. This requirement can extend from the return to the warehouse of an unserviceable assembly that requires movement off-site and purchase of the repair to the replenishment of high volume, but usually low-cost, workshop consumables. A resource acting as a purchasing officer will, according to prescribed guidelines, raise a purchase order on a supplier to satisfy the requirement.

With increasing volume, sophistication, complexity and risk associated with purchases it will be necessary to institutionalise the purchasing process through negotiated and generally fixed commercial terms through supply contracts. Deliberate and effective supplier relationship management coupled with increased systematic tools, such as automated purchase orders, approvals processes, invoice management and forward purchasing agreements will increase productivity by replicating desired processes, allowing for higher throughput without a commensurate need to increase management oversight costs.

These latter tasks and skills can generally be grouped under category management, which is defined as the task of optimising supply support through ensuring maximum effectiveness of the end-user–supplier business relationship.

Management should anticipate resistance from end users as initially unlimited flexibility in the source and conduct of purchase is reined in and institutionalised. The payback is in the considerable improvement in cost and quality control and labour productivity.

STOCK MANAGEMENT

Stock management should not to be confused with inventory management as stock management is the function typically responsible for the physical control and custody of purchased stock. Specific stock management tasks include:

- Recording the receipt of incoming goods and the issue of goods to end users, disposal, repair facilities or transfers to other warehouses in the supply system.
- Efficient and accurate assignment of incoming goods to storage locations and safe placement of goods in those locations. Stock placement requires consideration of the frequency of stock movements to reduce double handling and access time to receipt and issue. Common configurations of warehouse will see ‘bulk’ stocks stowed in racking specifically built for that purpose and with safe routes of access for the heavier materials handling equipment required. Once bulk stocks are broken open they will be moved to ‘break’ (intermediate-sized packaging) or ‘bin’ (individual unit sized packaging) to better utilise shelf space and facilitate access without the need for handling equipment.
- Physical preservation of goods according to the manufacturers’ requirements for environmental protection in support of warranty claims. Goods, including their packaging, which are subject to degradation by sun, rain, dust or vermin, will need suitable covered storage. Where goods have limited shelf life that is compromised by environmental factors then clean and/or cold rooms may need to be provided. Examples include various reagents, resins, rubber or vinyl products, clothing, etc. Competent purchasing practices can often specify packaging that greatly reduces the effort and cost of environmental protection, eg underground mining vent bags provided with ultraviolet (UV) resistant storage bags to permit them to be stored outside without cover indefinitely.
- Effective security of goods according to their risk of loss or theft. Inventory should be categorised by risk of loss or theft and security and stock counting processes established to permit the most cost-effective solutions. Potential inventory categories are
 - *Consumable, not accountable* – low value, low risk stock expensed when broken out of bulk stocks and counted no further at that point, eg workshop rags and minor items of office supplies. These are typically only managed in the inventory in bulk and are dispensed to the end user quickly or placed in unrestricted ready-use dispensers.
 - *Consumable and accountable* – forming the bulk of the typical inventory profile but not especially attractive on a unit basis. Need 100 per cent secure stowage and will need to be subject to a 100 per cent periodic stock counting methodology.

- *Valuable and attractive* – typically consumable and can be attractive because of their ready use or application outside the organisation, or are intrinsically valuable by composition, eg disposable batteries, car parts or diamond drill bits. These require a high level of supervision on an individual unit basis and need to be subject to high frequency 100 per cent stock counting. They should be stored in appropriately secure stowage with very specific access control.
- *Equipment assemblies, components* – these are typically valuable but not with a high risk of theft because either they are not readily moved without materials handling equipment or they have very limited applications. These goods require a higher level of stock accuracy and control because they typically become production stoppers when their loss or misplacement prevents the return to work of primary production equipment.
- *Capital* – these goods include the primary production equipment or supporting equipment, such as pumps, compressors and motors, and are managed through a capital asset register but are purchased and for the most part handled through the stock movement systems. When managed through the inventory they will require very close supervision and frequent 100 per cent stock counting, generally at the serial number level or via a dedicated rotatable pool management process. Capital cost accounting rules will define by value which items require capital asset management and tracking.

INVENTORY MANAGEMENT

Inventory management is a back office function whose primary role is to analyse end user requirements and historical consumption patterns in order to recommend the optimum stock holdings required at all levels of the inventory system.

Company inventory levels must be computed as a balance between the following factors:

- Balance sheet constraints identified by the chief finance officer.
- End user consumption forecasts provided typically by the operations, plant and maintenance managers.
- Stock holding, distribution and transportation constraints identified by the supply manager.

To set corporate inventory targets without achieving a balance between these three factors will encourage suboptimal service delivery performance and/or cost. For example, a financial cap on inventory independent of minimum consumption requirements or failing to recognise economic purchasing, transportation and storage costs will either drive stock outs or increase compensating costs in the end user or warehouse labour. An end-user-only perspective will often drive unnecessary buffering of stock to eliminate the risk of stock outs to a cost-ineffective degree. Finally, the supply service constraints and needs should not be driving end user access to stores without due regard.

Corporate stock holding policy is best set at 'weeks of stock held on the ground', rather than the common cash cap constraint. 'Weeks' of stock can be readily costed to support the approval process. Inventory management should recommend the stock holding level after taking into account all of the delay elements in the purchase and delivery of stock lead time, which include:

- *Administrative lead time* – commences when the end user registers a requirement for a stock item and completes when all approvals are in place, delivery arrangements are agreed and an order has been placed and accepted by the supplier. For automatic ordering

systems with online requisition approval hierarchies in place and the availability of common use goods already set by supply agreements, this step should not take more than one working day. This process can otherwise extend over months and needs to be well understood where the following circumstances apply

- more complex capital fabrication
- importation of production equipment from overseas
- extended development of specifications
- complex shipping arrangements
- the negotiation of warranties set to work and commissioning, supply of immediate life cycle and capital spares.
- *Vendor order lead time* – this delay period commences when the supplier accepts the order and completes when the organisation accepts delivery of the ordered goods. This delay element typically draws the most attention and is the easiest target for irritated end users. This is also the task where competent supplier relationship management by professional supply personnel can net the most cost-effective results. Bullying suppliers and the perpetual pursuit of the lowest unit cost in contrast to the lowest cost of ownership are common but typically unsuccessful or unsustainable strategies. Employing tools such as incentive- and performance-based contracts, automated ordering and invoicing and competent internal order management by the buyer are attractive tools and can be negotiated into rapid delivery lead times.
- *Internal delivery and receipt lead time* – mine sites must employ effective goods acceptance processes irrespective of whether they are direct to site or through multi-tiered warehousing systems. There is considerable merit in establishing performance tracking processes to ensure incoming goods are recorded as being received and when before they are released to the end users. Once end users identify the targets of their frustration any subsequent attempts to manage documentation processes will gain little to no effective attention, which leaves both accounts payable and supply with an administrative headache that quickly snowballs into additional remedial labour costs to catch up.

7.6.3 Transport

INTEGRATED LOGISTICS MANAGEMENT (OR SUPPLY CHAIN MANAGEMENT)

Mining organisations don't need to progress much further from their initial one or two site operations before logistics efficiency and costs will become an issue. Not necessarily because costs become prohibitive initially but because the distraction of management effort will start to impact on other potential revenue-earning functions. This is particularly true where the site is remote or offshore from the operations. Most people like to think they are capable of organising the delivery of an order but when done on an undisciplined basis by end users, costs, stock losses and production risks usually escalate quickly.

Supply chain management for the vast bulk of general purchasing is not overly complex, but if not coordinated and the actions of end users, suppliers, transport and warehouse personnel integrated then considerable scope for redundancy and duplication exists. The following considerations need to be explicitly addressed at each level of the supply chain:

- *Units of order, stockholding and issue* – optimising units of ordering to minimise order counts, transport costs and warehousing space will generally run counter to optimised customer service delivery. Purchasing and warehousing must cater for breaking down

bulk stocks into the units typically dispensed to end users. Contracting for bulk stocks prepacked in user dispensable pack sizes will attract a cost from the supplier but will ease the effort for dispensing and simplify stocktaking.

- *Consolidating orders* – from a purely supply systems perspective the most efficient order size is a single line. Where customers' distributed stores issue and replenish very frequently, stocking holdings can be maintained at a very low level. The resulting transactional workload, however, can be prodigious unless almost entirely automated. An example in recent years from a major Australian underground mining company that implemented high levels of automation in purchasing and a sophisticated stock distribution system saw a punishing increase in the transactional workload in accounts payable because of a significant lag in automation. The implementation of recipient-created tax invoices or other modes of e-invoicing would have provided very high levels of transactional efficiency over the entire procure-to-pay process. Conversely, consolidating orders and reducing the transactional load will require increased buffer stocks to cover the increased lag between end user requirement and delivery. There is a balance to be met there.
- *Transport planning* – transportation follows a similar argument in that frequent small loads delivery results in a high rate of response and keeps stock holdings down but at a much higher cost. In a transport market vulnerable to excessive and inflated fuel costs, the relative cost of capital to hold increased inventories and consolidate transport can be a very real alternative and needs to be competently costed. There is considerable merit in forcing the supplier base towards efficient stores delivery by consolidating across their customer base and sharing costs rather than milking each customer individually and inefficiently. It is an unfortunate fact that in many remote regions transport resources are limited and therefore extremely vulnerable to inefficient utilisation at inflated costs.
- *Optimised stock holdings* – determination of procurement strategies employing, just in time, *kan ban*⁴, or any other approach become meaningless unless the organisation has a firm grasp of all of the above elements and is able to forecast consumption, resupply lead times and the costs of resupply versus stock outs. Having determined the range, capacity and costs of transport and the capacity of storage available, economic reorder points and quantities need to be determined and actively monitored to ensure delivery meets the forecast. Unless very sophisticated modelling is employed, a new start-up will rarely achieve optimised stock levels overnight, but diligent oversight of supplier performance and internal delays will provide a sufficiently responsive feedback loop to allow correction within normal accounting management cycles.

7.6.4 Price and risk sharing with suppliers

Frequently, self-taught supply personnel pride themselves on their ability to beat a supplier down on price. This is inevitably a poor and unsustainable business practice and is usually paralleled by the buyer's complete inability to actually measure the supply chain performance anyway. Few successful suppliers ever deliberately lose money on a long-term supply relationship and considerable evidence is available to show where unsustainable pricing is compensated for by less conscientious and slower service, less flexibility to vary

4. Kanban (カンバン), literally meaning 'signboard' (<http://en.wikipedia.org/wiki/Signboard>) or 'billboard' ([http://en.wikipedia.org/wiki/Billboard_\(advertising\)](http://en.wikipedia.org/wiki/Billboard_(advertising))), is a concept related to lean (http://en.wikipedia.org/wiki/Lean_manufacturing) and just-in-time (JIT) ([http://en.wikipedia.org/wiki/Just_In_Time_\(business\)](http://en.wikipedia.org/wiki/Just_In_Time_(business))) production. According to its creator, Taiichi Ohno (http://en.wikipedia.org/wiki/Taiichi_Ohno), Kanban is one means through which JIT is achieved. Kanban is not an inventory control system; it is a scheduling system that helps determine what to produce, when to produce it and how much to produce.

from agreed arrangements and lower priority for constrained supplies. A major mining company in the north-west of Western Australia effectively drove skills out of their major support base just prior to a period of massive sector growth and subsequently paid the penalty in extraordinary labour rates. Far better and sustainable results can be gained by paying a fair price but devoting the primary effort to understanding both the organisation's and the supplier's supply chain so that a level of confidence is held by both parties about what costs are fair and reasonable. This has been proven to be the key to successful supply and risk sharing between competent business entities over extended periods. Risk should be apportioned with price. It is not a sustainable strategy to beat the supplier to a minimum profit position then expect them to carry the risk for poor internal supplier chain management. If both parties have a competent view of each other's cost base then the buyer can push the risk and cost of holding buffer stocks, smoothing peaks and troughs in transport loads and market price movements back to the supplier. Typically contracted arrangements facilitate and institutionalise this kind of business behaviour.

7.6.5 Contracts and supply agreements

While every purchase order is a contract in itself, the commercial terms typically associated with them are generic in nature without any specific performance or risk management coverage. They are typically generated by finance to cover payment terms and addresses for notices, submission of invoices, etc. Almost every enterprise management system used in supply today has the capability to stream purchasing through a series of predefined gates, where for a catalogued stock item the supplier and, therefore the key commercial terms, can be fixed and automated to varying degrees in the procurement process. When backed by a supply contract or agreement these processes, variously known as forward purchase agreements (FPAs) or customer service agreements (CSAs) can increase purchasing productivity by up to 60 per cent while reducing the effort devoted to transaction error, correction in purchasing, warehousing and accounts payable dramatically.

Supply contracts (or agreements) should not be seen or used as weapons against either party or a prop for some administrative empire. They should be scalable for risk and spend and balanced for both the buyer and the supplier. They are not the exclusive province of lawyers and require a healthy balance of field experience to make them work. As an illustration, a major Perth supplier entering into a \$10 M agreement with an offshore mining company for consignment stock tasked a major legal house to write them a supply agreement to protect their interests. The result was a 70 page document that was abandoned by both parties because it lacked any knowledge of how the supply was to be effected and was so onerous as to be unworkable. At the end of the day the commercial principals sat around a table and compiled a workable solution before submitting it to a legal specialist for a legal safety check.

The contracts need to focus on:

- the supply chain risk about transfer points in the shipping process
- insurance
- timing and delays
- product quality and compensation
- packaging for both sea and land transport and handling at the destination
- price control and variation
- supply chain performance reporting and responsibilities.

As well as the expected:

- address for notices
- payment terms
- disputation processes and *force majeure*.

When such a contract for the supply of goods is effected they can usually be mirrored as a forward purchasing agreement (FPA) in the supply part of the enterprise resource management system to significant advantage. Typically an FPA achieves:

- control over the choice of supplier, preventing unauthorised escape spend
- control over fixed pricing because a variation requires a defined process and a new price list load
- explicit time stamping of key activities against the contract, supplier and the stock code, such as time requisition submitted and approved, order placed, stock received and issued to the end user, etc
- assurance for the supplier that their commitments are backed by institutionised action from the buyer's side.

More mature supply systems in multinationals like BHP Billiton and Barmenco can consistently achieve better than 80 per cent of their spend automated and on contract, which gives them the very obvious commercial advantage of very high order placement rates with a small number of purchasing staff and very limited overheads in error management.

These same multinationals also enjoy considerable benefits from the supplier relationship management that is possible under such structured purchasing arrangements. There are very clear and frequent examples where suppliers will give preferential treatment not to the highest paying customer but to the one that generates less noise and effort to conduct a given high volume of business. This has been most evident during the mining sector downturns of the Southeast Asia collapse and the recent global financial crisis, where companies with a scalping approach to purchasing found themselves on the outer or paying significant premiums for strategic critical supplies in contrast to protected stock for customers with long-term supply relationships.

Supply contracts need not be tomes with the value measured by weight. A common and successful strategy is to prioritise the risk of supply arrangements and utilisation of short form tenders and contracts, particularly for small services, where the administrative effort doesn't need to be duplicated for each requirement. Even high value and high risk contracts can be templated where a requirement is repeated across an organisation.

7.6.6 Supply system performance management

The adage that you can't manage what you can't measure is especially applicable in supply chain management. Given the supply chain is complex and is usually a major part of any organisation's audit compliance regime it is extremely vulnerable to manipulation both from end users and the supplier base. The only effective defence is accurate and timely performance and exception management of the transactional flow and outcomes. The following are commonly recommended measures and what they achieve. There are many more but every measure comes at a cost so if those listed below can be achieved a reasonable level of confidence in the function's performance can be expected.

Warehousing: the primary result is the effective customer satisfaction rate at the first point of enquiry at the warehouse counter (otherwise known as the fill rate). This should exceed

95 per cent. Other measures such as effective completion of receivals, picking and issues are required to measure staff utilisation and productivity. Warehouse packing density is an issue for large sophisticated systems but is not usually practical for the limited facilities typical of mining companies.

Transport: schedule compliance for a given capacity is a key indicator if the internal supply chain is to meet forecast performance. Trucking efficiency is usually managed by capacity utilisation, but it needs to be recognised that many mining outfits operating in remote areas will need to run suboptimal loads simply to maintain the flow to meet production.

Purchasing: order throughput is useful for resource management but the health of the system is realistically reflected in the size and age of the outstanding order file. There is a natural tendency for purchasing officers to focus on getting the orders out of the door at the expense of chasing yesterday's orders. Failure to manage that will lead directly to end user frustration, leading in turn to redundant ordering or bypassing the approved purchase processes.

7.7 LAND ACCESS AND COMPENSATION MANAGEMENT

This section deals with land access and land compensation issues in the domestic Australian context. It is presented under the following subheadings:

- the context of land access for minerals projects
- a 'best practice' approach to land access
- a suggested compensation practice for land acquisition.

7.7.1 Context for land access for mineral development projects

The basic context under which land acquisition takes place with mineral projects includes the following points:

- in most situations minerals are the property of the Crown (state government) and they generally occur below the surface of Crown or freehold land so access needs to be negotiated on a case-by-case basis
- mining company access to private and public land builds on the foundations established through the exploration phase
- an exploration licence issued by the Minister for Mineral Resources is a precursor to a mining lease, which is issued once project approval is granted
- a social licence to operate is built on past performance and relationships with landowners and communities where companies operate
- each state will have legislation and templates (provided by industry peak bodies) that guide negotiated land access for exploration and mine development
- mine development can only occur once a comprehensive environmental impact assessment of the project has been undertaken, exhibited publicly and approved by government
- land ownership by the mining development proponent is normally requisite because of the need for unrestricted access to the land to develop a mine

- mining can create ongoing liabilities (voids, contaminated land), which will require ongoing monitoring (not a responsibility that other parties would likely take on)
- development consent is conditional and is granted to projects that can demonstrate that they are an ecologically sustainable development.

7.7.2 Leading practice approach to land access

The feasibility study of a mining development can take several years to achieve bankability and it is generally in neither party's interests to enter into property transactions in the early phases of development.

Open and transparent communication between the mining/exploration company and landholders is essential to keep landowners fully informed of project development progress and potential future scenarios.

Mining company representatives, including field technicians, geologists, engineers, scientists and directors, will generate trust and cooperation from landowners if they demonstrate shared values.

There needs to be mutual understanding of both parties' expectations regarding access and compensation for any loss or inconvenience to the landowner caused by the project.

Almost every landholder will have a unique view and position on the concept of their assets being acquired by a mining company. The proponent should gather data on people and communities to understand the perspective from the landholder's side of the negotiating table. Mining company negotiations should be fair to all parties. It is standard practice to pay reasonable costs for legal and financial advisors to landholders (compensable loss). To be successful mining companies should:

- develop a community engagement strategy that includes dialogue and interaction with neighbours and other stakeholder/interest groups (eg local progress association)
- engage stakeholders at an early stage, eg exploration.

Larger organisations may have dedicated community relations staff but every organisation should have a clear strategy for each project from its inception, which includes who needs to be engaged and consulted and when.

Interest groups can include local non-government organisations, specific interest groups, traditional owners, near neighbours or local communities that could be impacted.

If an exploration or mine feasibility effort is likely to be prolonged over several years, consider establishing a shopfront for the organisation in the local town or village. Provide an 'open door' to community to engage with the organisation.

Landowner's rights and individual situations should be understood and respected (formalised in Land Access Agreement documents).

As a 'golden rule', apply common sense when operating on someone else's property. Leave gates as they are found. Report incidents to the landholders and follow industry guidelines on procedures for land access. Integrate exploration activity with farm activity schedules; for example, do not plan disturbing activities in a paddock set aside for lambing ewes.

7.7.3 Compensation for exploration and mining

Most industry bodies will have a scale of compensation rates commensurate with the level of disturbance by exploration activities. Organisations should avoid the path of paying whatever it costs to gain access as word will eventually spread that Organisation X paid \$Y

per drill hole. This creates unrealistic expectations for smaller explorers to compensate at the same rate as Organisation X.

Compensation needs to take into account the variations in productivity of the land being disturbed, for example, semi-arid land is not as productive in an agricultural sense as high rainfall improved pasture.

Most states have templates for land access and in some states legislation requires formal land access agreements to be in place before any access can be granted for exploration. As projects mature or become more intensive in their exploration an option to purchase or lease the properties affected can be negotiated.

Agricultural production can co-exist with exploration and mining activity as some organisations have been demonstrating for decades. Refer to Figures 7.7.1 and 7.7.2.

FIG 7.7.1 - Caloma reverse circulation rig with header harvesting crop.

In the current political climate, in some states, with mining seen as a threat to agricultural land and water supplies it is important for the mining industry to demonstrate both industries are essential for the resilience of regional areas (where most mining activity occurs).

Exploration for minerals in most instances does not result in economic projects but if a mine does look feasible then consider a formalised offer to purchase the property should the project prove viable.

Negotiate put and/or call options with landowners during the project feasibility study period that provide sufficient incentive/compensation to the landowner while not compromising the feasibility of the project.

Independent valuations should be obtained as a base for negotiating an appropriate price for property acquisitions (valuation × multiplier). A multiplier is an incentive provided to the landowner that makes the prospect of selling land, which will likely have high sentimental value, more attractive. Every project will have a different starting point for negotiations. It is

FIG 7.7.2 - Wyoming Three resource drilling in wheat.

important, however, that confidential negotiations are seen to be fair and within community expectations in the event that prices paid are eventually inadvertently disclosed.

Call options are a relatively low-risk path for mining companies and can simplify access and provide reliable income to the landholder. There may be opportunities to contract some work to landholders who have good knowledge of their own land and usually equipment on hand for rehabilitation-type activities.

Call options should be exercised as soon as practicable once project approval and a mining lease is granted.

7.8 OPERATIONS REPORTING

There are many reasons why operations reporting is critical to the success of a mining operation no matter how small, large or complex that operation may be. Every operation has its own unique challenges and therefore the operating reporting structure and systems need to be developed to meet the requirements of that particular operation.

It is not a case of just utilising an operating reporting system from off the shelf and implementing it. Careful consideration of what is required and how an operational reporting system should be implemented needs to be thoroughly thought out to achieve the optimal outcome. This section highlights the key aspects of operations reporting to assist a mine manager to develop, select and implement an effective operations reporting system. Chapter 8 (section 8.2) builds on this material and a pro forma operations report is provided in Appendix 3.

7.8.1 The importance of mine operations reporting

The key factors that a mine manager needs to focus on to optimise a mining operation are the following:

- planning
- process management
- asset management
- scheduling, resourcing and execution
- reporting, reconciliation and optimisation
- people and workforce practices.

As can be seen from the above list, reporting, reconciliation and optimisation are presented as single element, but in fact operations reporting links all the above elements to ensure that the mine manager has a full understanding of what is actually being done or in some cases what is not being done, thus identifying what is required to optimise the operation.

Put another way, operations reporting is all about effective communication.

There are times when what is planned to optimise an operation is being ignored due to other immediate pressures and the plan can be lost in the noise of the site communication network.

One of the major success factors in any organisation is how effective the communication is within in that organisation. Mine operations reporting systems are the backbone to all communication across an operation. The more effective the reporting systems, the more effective the communication will be, which in turn will lead to increased productivity and reduction in wastage. Such systems are also a very effective management and leadership tool.

From a management perspective it is often a fact that what gets measured gets managed. From a leadership perspective it creates direction and motivation to achieve the desired goals in an efficient and safe manner. If there is clarity in what tasks need to be done and what the expectations are in terms of desired outcomes then there is a very good chance that these goals will be achieved. An achieving team is more likely to be a motivated team.

Well-thought-out reporting systems will link the activities in an operation to achieve corporate goals.

There are some operations that simply do not follow production and development schedules in order to keep people and equipment fully utilised; however, this may compromise the optimal output to achieve the overall operational production profile. Some operations do not measure adherence to these production and development schedules and there are some operations where the overall organisation of activities appears ad hoc and there is a sense of chaos and general wastage. One must then question whether there is effective communication within the operation and one of the first things to look at is to see how effective, or otherwise, the operational reporting systems really are. Invariably there are opportunities to improve the reporting systems and consequently improve communication and increase productivity. Operational reporting systems also drive behaviours of the operating teams.

If you have an effective and well-thought-out operating reporting system you can create an environment of desired behaviours. The opposite can occur if you have an ineffective system. For example, you can measure the number of buckets (and their associated weight) that a loader may tip into a crusher during a working shift. This would be a normal and important performance measure in an operating mine. However, is this measure the most appropriate KPI to measure the performance of the loader operator?

If this was the operator's KPI then the likely aim would be to get the maximum number of buckets to the crusher in the working shift. At first sight, one might think that is exactly

what should be achieved, but in fact it is not. What should be achieved is the optimal and sustainable number of buckets delivered to the crusher over several shifts, days, weeks, months and years. So what is required to achieve the optimal and sustainable number of buckets to the crusher? There are many factors that will impact on this KPI, which include:

- optimal availability and utilisation of the loader (operator care and maintenance support)
- steady supply of ore feed for the loader
- crusher availability (adequate surge capacity)
- effective hours of loader operating hours (delays to operations)
- equipment damage (housekeeping, spillage, etc)
- road conditions and other environmental conditions.

This is not an exhaustive list; however, it provides an example of ‘what gets measured gets managed’. In the longer term, it is undesirable for an operator to go flat out during a shift to achieve a record number of buckets to the crusher when the end result might be to have the loader in the workshop for unscheduled breakdown maintenance. In this example the shift supervisor may focus on general housekeeping matters and good operator care of equipment to achieve KPI targets for loader utilisation and availability.

Operational reporting systems can form the key aspect of the working culture of mining operations so it is imperative that the most appropriate system is developed and implemented. Thorough planning, effective operational reporting systems, adherence to plans and solid communication are all certainly important steps towards achieving an optimal operation.

7.8.2 Establishing operations reporting systems

There are many forms of operational reporting systems. Some systems are highly sophisticated and use leading technology to measure activities in an operation automatically and in real time. Some are simple and rely on paper trails supported by good verbal communication. Most operations use an element of sophistication and conventional forms of communication. No matter what reporting system you employ into an operation it must be relevant to achieving the overall operational objectives.

The key elements of an effective operations reporting system will be:

- linkage to corporate goals and objectives (high-level KPIs)
- linkage to achieve LOM plans
- prioritised activities to achieve production and development schedules and not to keep operators and equipment busy
- safety as both leading and lagging parameters
- maintenance activities as an integral part of the plan
- measure to adherence to production and development schedules
- measurement and monitoring of deviation to plans, with plans being continually modified to optimise operational performance
- focus on what is required to achieved KPIs
- monitoring systems linked to achieve desired behaviours of the operational teams
- sophistication of the systems being appropriate for the operation
- measurement of downtime and wastage being measured as opportunities for improvement

- the system as a motivational tool with realistic and relevant targets to create desired individual and team behaviours that build to achieve the plan with a minimum of wastage of effort and resources
- reconciliation as an ongoing process.

So what are the first steps in developing an effective operational reporting system? The first step is to review what the corporate goals are. What is the strategic planning process? Following are three elements in the strategic planning process:

1. strategic planning – LOM, addressing how all the known and anticipated mineralised areas will be exploited
2. business planning – the annual budget and a five year rolling plan, which will be of greater detail than the strategic plan
3. operational planning – taking the annual budget to monthly, weekly and daily plans is covered under scheduling and delivery.

A thorough review of these strategic plans needs to be carried out to fully understand what the key deliverables are for an operation. There are no short cuts with the strategic planning process because if the mine manager gets this wrong it will certainly be detrimental to the mine's operational performance, which could prove to be very costly further along the track.

The purpose of the strategic planning process is to determine the following:

- capacity of the orebody
- exploration requirements
- geological and geotechnical parameters
- development priorities
- mining methods
- production drilling and blasting requirements
- ore transportation
- surge capacities (stockpiles and orepasses)
- mining activities
- development and production scheduling
- mining costs.

This is not an exhaustive list; however, it gives the reader an idea of how the strategic planning process determines the key drivers for an operation and consequently the reporting requirements.

Once a mine manager has established what the key deliverables are for the operation the next step is to gain a full understanding of the mining process. Figure 7.8.1 is a schematic for an underground mining operation outlining the key ore stock movements from initially accessing an orebody to delivery of the product to market and the mining activities that support the mining process.

Many operations do not take this holistic approach and consequently the operation is compartmentalised in silos and there is not a good understanding of what the key drivers are trying to achieve for the overall objectives of the organisation. Following are some examples of how mine managers can focus on the wrong drivers:

- attempting to maximise production drilling performance when the real driver is to increase development to provide more drilling locations

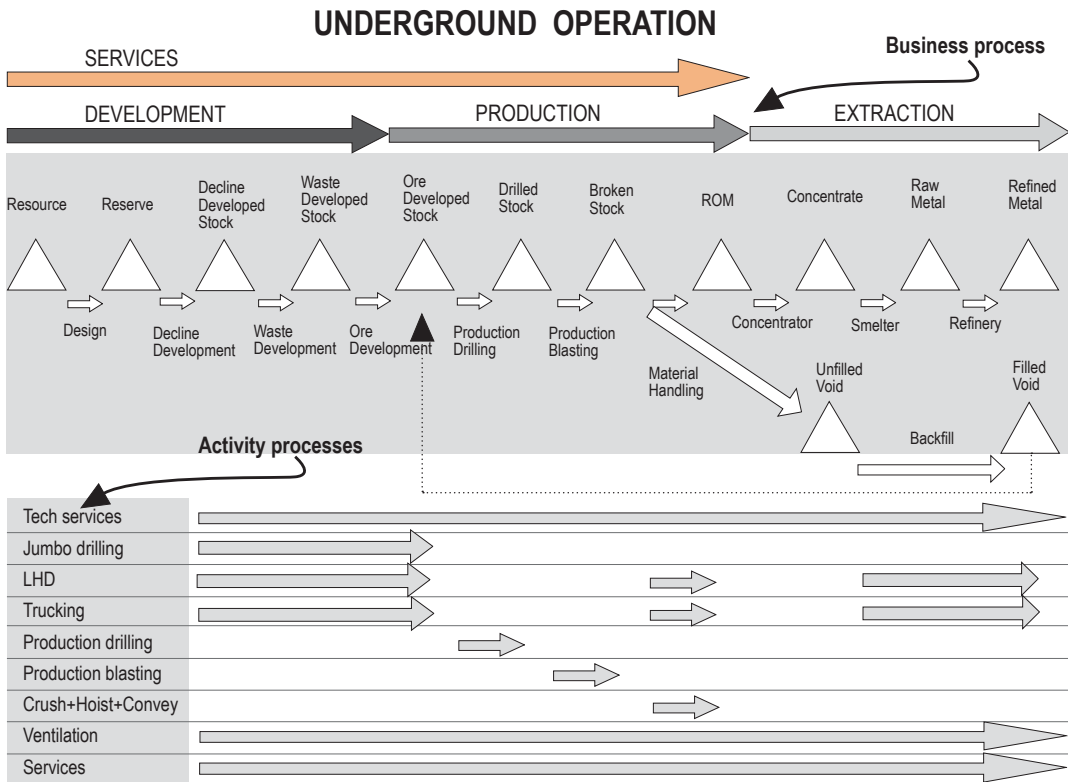


FIG 7.8.1 - Schematic for an underground mining operation.

- production drilling and blasting engineers reduce primary blasting costs; however, this causes larger fragmentation, increased secondary breaking activities, blockages in chutes, etc and this in fact reduced mine productivity and increased overall mining costs
- shift supervisors directing their operators to work in non-priority locations to keep them busy, which actually reduces the overall head grade of ore delivered to the processing plant.

It is important that a mine manager fully understands the mining process and takes the time and effort to identify the key bottlenecks. Having this holistic approach, or having the bigger picture in mind, is imperative if he/she is to determine the real key drivers for an operation. It should be noted that on many operations the management team is totally focused on mining activities and can thus lose sight of the mining process; consequently focusing on the wrong drivers to optimise the overall performance of the operation.

A review of the mining process should be carried out annually as the bottlenecks can vary as the mining operation evolves.

When the mine manager fully understands the key drivers for the operation the next step is to determine what needs to be measured to achieve these key drivers and what metrics are to be used. Just measuring, such key drivers such as development metres, longhole drilling targets, or production tonnes moved, will not achieve the optimum production profile for the operation. In essence, what needs to be measured are the activities that are required to prepare a bench or stope for production.

In an underground environment this is called stope preparation. Examples of some of the stope preparation activities are provided below:

- backfilling
- ventilation and others services such air, water and power
- stope access development
- rehabilitation of old drives
- ramp and general road works
- drill site preparation including survey mark-ups
- mine plans for operators.

Although not an exhaustive list, it should give the reader an idea of what is required to be measured to establish sustainable production fronts. These activities need to be prioritised so that the overall operational plan can be achieved in a systematic manner.

Asset management is another element needing to be measured and monitored and must be incorporated into the mine scheduling and mining activities. Reliability of fixed and mobile plant in a mining operation is critical. Again, a mine manager must take special care to measure what is required to achieve optimal reliability of equipment. Below are some examples of these activities:

- planned and shutdown maintenance scheduling
- breakdown and unplanned maintenance
- opportunity maintenance
- equipment damage (how, where and what can be done to reduce reoccurrence)
- availability of spare parts
- effectiveness of bill of materials (BOM).

Although once again not an exhaustive list the reader should gain an understanding that it is not just a case of measuring availability and utilisation of equipment.

In summary, the operational reporting systems are established by understanding the key drivers from the strategic plans, the mining process, the mining activities, asset management, and above all to measure and monitor what is required to achieve key drivers.

Once a robust reporting system has been established the next step is to measure adherence to the plan. It is pointless implementing a robust reporting system based on the above criteria if operators ignore the plans. It is good practice to also measure adherence to plans weekly and to carry out a reconciliation process monthly and then adjust the planning schedules accordingly.

Annually, it is also good practice to determine the variability and volatility of an operations' performance where:

- variability is a measure of how *predictable* the operation is at achieving its business plan
- volatility is a measure of how *consistently* the operation is utilising its capacity.

Continually measuring and monitoring adherence to plans, as recommended above, may change management's focus from time to time and accordingly they should revisit what is reported to meet that change in focus. Mining operations continually change as the mining production fronts progress and consequently so do the drivers and reporting requirements.

7.8.3 Communications at shift change

The change of shift meeting is one of the most critical functions at any operation. This meeting is effectively the point at which all planning and preparations are to be executed. However, the change of shift meeting is not only critical in deciding how to execute the operational

plan as efficiently as practicable but it also drives the behaviours and work practices of the operators. Safety should be paramount at these meetings and there should be a strong focus on how to continually improve work practices in the safest manner. For this reason safety should be the first item on the agenda at a change of shift meetings. Safety issues can be covered in various forms, as follows:

- safety message that creates an awareness
- hazard reporting (proactive approach to preventing an incident)
- incident reporting (lagging approach; however, the learnings are also preventative measures)
- housekeeping and general safety culture
- job safety assessment and planned workplace inspections.

The most important driver in discussing safety issues at the change of shift meeting is to develop a culture or a state of mind in the operators that prevents injury (or damage to equipment) at all times. Operations are continually changing and communication on the importance of safety is essential to retain this safety culture awareness.

Safety is a common theme for all operations; however, after that the change of shift meeting takes many forms. On very small and non-complex operations it is quite common for the 'traditional' approach to communication to be adopted. This is where a shift supervisor hands out instructions to the operators and keeps them abreast of all the activities. These shift supervisors are like conductors of an orchestra as they are determining where and when activities must be carried out. This approach, however, may not be appropriate on larger or more complex operations.

On larger or more complex operations the shift supervisor becomes a facilitator at the change of shift meeting. Communication between operators and the shift supervisor facilitates these communications and adds input by exception. Communication between operators in this type of shift change can also take a variety of forms.

In some cases the operators will report at the end of the shift to both crews on a particular mining activity regarding the status of the equipment, work location and what the plan is for the next shift. In some cases the communication between the operators is only to their counterpart on their next shift with the overall operational plan presented on screens in the change of shift office. Another configuration of this type of shift change is the oncoming crew has a brief meeting with their shift supervisor and previous shift supervisor and then the operators 'hot seat' the shift change communication with their counterparts on the job.

It is also good practice to have technical support staff attend at least one change of shift meeting a day (normally at the beginning of day shift). Geologists, geotechnical and mine planning engineers make themselves available to provide the technical information that is required for the operators to carry out their tasks. This could include reference to issues such as grade control, ground support requirements, drill and blasting patterns, etc.

The style of the change of shift meeting depends on the size and complexity of an operation and the technology that is being adopted at an operation. Note that it is possible to have a large mine that is not very complex and the scheduling of mine activities is fairly straightforward. Conversely a small mine may be very complex in terms of scheduling a lot of mining activities with a high turnover of stoping areas.

Technology also plays an important role in how a shift change is structured. If a mine, for example, implements a supervisory and data acquisition system (SCADA) that measures and monitors the performance of plant in real time, then this information does not need to

be provided at shift change. Also applying a 'traditional' shift change configuration would probably not be appropriate as the operators would have the information available at all times and the decision making then becomes the responsibility of the operators, which is supported but not directed by the shift supervisor.

Skill levels of a workforce can also have an impact on how a change of shift meeting is structured. There could be language, or culture challenges and it may be totally inappropriate to apply a 'traditional' shift change configuration.

The other aspect of a good change of shift meeting structure is not only the management component (measuring and monitoring) of an operation but also the leadership component (motivation of desired behaviours). A well-structured shift structure can highly motivate the working teams if they feel part of the communication. On the other hand, a poorly structured change of shift meeting can do the reverse with crews blaming each other, or blaming the shift supervisor or management for poor performance or whatever other inadequacies may be prevalent in the operation. A well-organised operation is normally a reflection of how good the communication is amongst the different departments within that operation. This communication is ultimately used at the change of shift meeting and the leadership shown here will make a difference in getting the most out of the resources available.

There is no standard format for a shift change meeting as each operation has its own unique challenges and therefore a lot of thought is required to design and implement the most appropriate structure to execute the operational plan effectively and safely. It is good practice to review the change of shift structure on an annual basis to fall in line with the overall operational reporting review.

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Various chapters within this book:

- The strategic planning process, Chapter 10.1
- Risk management, Chapter 10.5.

Useful links

BHP Billiton, Fatal Risk Control Protocols: <http://www.mirmgate.com.au/docs/BHPBilliton/FatalRiskControlProtocols.pdf>

Department of Primary Industries, Earth Resources in Victoria: <http://new.dpi.vic.gov.au/earth-resources>

Government of South Australia, DMITRE Minerals: <http://www.pir.sa.gov.au/minerals>

Government of Western Australia, Department of Mines and Petroleum: <http://www.dmp.wa.gov.au/>

New South Wales Government, Division of Resources and Energy, Minerals and Petroleum:

NSW Mining Design Guidelines: <http://www.dpi.nsw.gov.au/minerals/safety/publications/mdg>

NSW Minerals Industry Safety Handbook: <http://www.dpi.nsw.gov.au/minerals/safety/publications/workbooks/safety-handbook>

Northern Territory Government, Department of Resources, Minerals and Energy: http://www.nt.gov.au/d/Minerals_Energy/

Review of the Mines Safety and Inspection Act 1994: http://www.wairc.wa.gov.au/Files/DiscussionPapers/MI_Act_KennerReview1994.pdf

Queensland Government Mining and Safety: <http://mines.industry.qld.gov.au/>

Safe Work Australia: <http://www.safeworkaustralia.gov.au/IndustryInformation/Mining/Pages/Mining.aspx>

United States Department of Labor, Crandall Canyon Mine: <http://www.msha.gov/Genwal/CrandallCanyon.asp>

Workplace Standards Tasmania, Mine Safety Laws: http://www.wst.tas.gov.au/industries/mining/mine_safety_laws

CHAPTER 8

FINANCE AND ADMINISTRATION

Sponsored by:



BHP Billiton is the world's largest diversified natural resources company. Its objective is to create long-term shareholder value through the discovery, acquisition, development and marketing of natural resources.

BHP Billiton is amongst the world's largest producers of major commodities, including aluminium, nickel, copper, energy coal, iron ore, manganese, metallurgical coal, silver, titanium minerals and uranium, along with substantial interests in oil and gas.

A global organisation with over 100 locations throughout the world, its success is underpinned by the 100 000 employees and contractors that work at BHP Billiton.

It has an unrivalled portfolio of high-quality growth opportunities that will ensure it continues to meet the changing needs of its customers and the resources demand of emerging economies at every stage of their growth.

BHP Billiton has a proven record of delivering superior shareholder returns through the disciplined execution of its unchanged strategy of owning and operating large, long-life, low-cost, expandable, upstream assets diversified by commodity, geography and market.

Its assets are operated under a simple and scalable organisational structure supported by standardised, controlled processes, allowing its people to focus on what is important. BHP Billiton's Charter, which defines its values, purpose and how it measures success, together with the Code of Business Conduct, are the foundation documents of the Company.

BHP Billiton is committed to the health and safety of its people, the environment and the communities in which it operates. The long-term nature of its operations allows the establishment of lasting relationships with its host communities, working together to make a positive contribution to the lives of people who live near the operations and to society generally. Its ability to grow in a safe and environmentally responsible way is essential.

As a globally significant producer, exporter and consumer of energy, BHP Billiton is committed to managing the risks of climate change. It actively seeks to reduce water usage and carbon emissions across the business, monitoring and reporting on these annually in its sustainability report.

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8.1 MINE ADMINISTRATION FUNCTIONS

Mine administration may be regarded as a grouping of all of the business activities surrounding a mining operation that are not core to the usual production activities, such as exploration, mine geology, mine operations, ore processing and mine maintenance. Organisationally speaking, it is often the case that all of the non-core functions are grouped together and placed under the responsibility of an administration manager or as a subset of the finance and administration manager's responsibilities.

In this section, mine administration functions are described in terms of a single, standalone operation, though the same principles will remain with a larger organisation – the only difference being the degree of centralisation of some of the functions.

For the purposes of this section, we will also assume that the personnel and human relations roles are not allocated a separate organisational responsibility, though this would undoubtedly be the norm in a multi-operation organisational structure. We have also excluded occupational health and safety, assuming this to be a separate organisational function if not spread over the operational centres.

For ease of reference, the most common mine administration functions are set out below under their main headings, which are followed by additional subheadings, so as to offer a form of checklist for establishing mine operations, or auditing ongoing operations:

- personnel and human relations
- accounting and control
- supply and warehousing
- camp or village operation
- major contracts
- logistics, and possibly
- liaison with external stakeholders.

Each of these headings is now discussed in more detail in the following subsections.

8.1.1 Personnel and human relations

As a starting point, readers are referred to Chapter 5 of this handbook for an overall coverage of this topic. At a mine site level, however, it is possible to distill much of what is set out in Chapter 5 into a checklist of 'must-have' capabilities. These are set out below:

- organisation design and development
- recruitment
- education, training and development
- performance appraisal
- industrial relations.

8.1.2 Accounting and control

Assuming that the mine operations are conducted as a separate reporting entity or business unit, then it is considered that the following functions would be necessary as a minimum:

- mine accounting and bookkeeping
- accounts payable
- payroll
- risk management
- management cost reporting.

Added to these functions may be those associated with supply, though we have treated those as a separate section below.

8.1.3 Supply and warehousing

The additional functions to be included in this administrative unit are:

- purchasing
- warehousing and stores control
- inventory and asset registers
- major contracts
- freight consolidation and forwarding
- security.

8.1.4 Camp or village operation

The principal administrative functions under this subheading would normally include:

- camp management
- catering and cleaning contract management
- camp maintenance
- related camp logistics and amenities.

8.1.5 Major contracts

The major contracts at the mine may be the responsibility of the relevant operations section heads, but there must be, however, adequate liaison with mine administration, as this is where the contract payments will ultimately be processed. The major mine contracts usually include some or all of the following activities:

- mining or earthmoving contract
- fuel contract
- various maintenance contracts
- service contracts for major consumables
- camp catering contract
- commute contract with an airline
- off-take contacts with customers
- security.

8.1.6 Logistics

Under this heading, the following support services would normally be included:

- transport
- communications

- shipping and or shiploading
- supply (if not included in section 8.1.3)
- disaster or emergency management
- security.

8.1.7 Liaison with external stakeholders

This topic is dealt with in more detail in Chapter 4. Liaison with the world beyond the mine boundary is arguably directed and controlled by mine management, but is usually implemented by the mine's administration department. No matter how much external relations (ER) is decentralised to a head office function, there will always be localised ER to deal with at a site level. How much there is and how far up the scale it goes, will always depend on the organisation concerned.

The following list suggests those areas of localised ER responsibilities, though some organisations will require additional external facilitation. As a general rule, any ER issue that affects more than one operation may best be dealt with off-site by general management. For this reason the list presented here has a localised focus:

- liaison with regional regulators such as the Mines Inspectorate
- liaison with the regional Shire Council
- relations with the regional community or township
- relations with regional landholders
- liaison with police and customs in some circumstances
- relations with Aboriginal or Islander communities
- dealing with mine visitors.

It is recommended that each of these subheadings be reported on when preparing the monthly operations report for the mining operation as a whole. More comment will be offered on operations reports in the following section.

8.2 THE MONTHLY OPERATIONS REPORT

As mentioned in section 7.8 in the previous chapter, it is considered to be standard industry practice at operating mines (and developing projects) for there to be an operational or project report on a regular basis. In this section, an explanation will be set out as to why monthly reports are produced. A template is provided in Appendix 3, aimed at making it easier for managers to create their own, as and when needed.

Monthly or bi-monthly operations reports can vary quite considerably in content and detail depending on the size and nature of the organisation. In the case of the smaller companies with only one/few production units the monthly/bi-monthly reports are largely or totally the responsibility of the registered manager, whereas with larger companies owning many operating mines the reports by the registered manager are less voluminous whilst still containing all essential and relevant site information.

Regardless of their size, internal company reports should be viewed as part of the organisation's planning and monitoring process and their content should relate to the organisation's operational goals, financial reporting requirements and compliance with relevant laws and regulations.

Monthly/bi-monthly reports are primarily for the use of the managing director and members of the management group and should always start with a short succinct executive summary and address such issues as:

- the performance and efficiency of the various operational units
- operational compliance with organisation values
- health and safety issues and assessment of risk management methods.

In the case of smaller developing mining companies these periodic short-term reports produced by the resident manager / general manager will include fairly detailed sections dealing with the following topics:

- occupational health and safety (eg key performance indicators (KPIs), lost time injuries (LTIs) and medical treatment injuries (MTIs) per period)
- human resources (eg personnel turnover per period)
- environmental management (eg key KPIs, environmental compliance activities or incidents per period)
- mine physicals performance (eg key KPIs, such as ore tonnes and grade for the period, development metres advance, etc)
- mining engineering issues (eg mine design and/or projects progress and status)
- processing plant performance (eg key KPIs, such as process plant availability, recovery, throughput per operating hour, etc)
- infrastructure and asset management (as applicable progress and status)
- exploration activity (eg major targets, number of drill rigs, etc).

In the case of larger companies their exploration program, financial/asset management and elements of resources management, etc may well be managed and controlled centrally and consequently the mine's period report will concentrate mainly on safety, operational and on-site financial issues.

Larger multi-site company reports may therefore be structured along the following lines:

- operations summaries – defining the main operational details and KPIs for each site as outlined above, etc
- financials – profit, loss and appropriation account for the period, balance sheet for the period, key KPIs such as cash cost per tonne of ore and per unit of metal (eg gold per ounce or nickel per pound of concentrate)
- capital program – capital report, details of lease expansions, etc
- exploration – details of exploration at various sites
- administration – share registry report, sealing ratifications, etc.

8.2.1 The purpose of operations reports

Operations reports have both an external and internal function, as outlined below.

Internal functions:

- inform all of the mine's organisation structure (but especially senior management) of key performance, operational and cost data, which may be needed in connection with their organisational roles
- impart training and a sense of preferred operational culture
- provide a permanent, historical record of what the mine was doing and how it was performing at a given point in time

- provide an operational and cost record, built up over time, upon which various mine-related analyses may be undertaken in order to improve operational efficiency.

External functions:

- provide a basic record of production performance and costs for a given operation at a given point in time
- enable divisional offices to compare performance of similar operations with a view to operational improvement
- allow accounts for each mining operation to be consolidated, where necessary.

8.2.2 The operations report – a contents template

Typically, operations reports are broken down into sections, which, broadly speaking, are aligned to the mine's operating departments. For example, at the simplest level, a report might include sections dealing with production, accounts and administration. More commonly, however, a greater number of subheadings are usually used, as suggested in Table 8.2.1.

Appendix 3 of this handbook contains a template for a typical operations report, which shows the breakdown of the nine report headings that appear in Table 8.2.1.

TABLE 8.2.1
Typical operations report contents (by major heading).

Section	Department	Activity
1	Management	Executive summary
2	Exploration	Exploration status
3	Project operations	Mining, milling and product handling
4	Occupational health and safety	Safety, training and hazard analysis
5	Personnel and manning	Manning charts
7	Environmental management	Monitoring and compliance
8	Administration	Administration and supply
9	Management cost report	Cost reports

8.3 MINE ACCOUNTING

8.3.1 The role of the mine accountant

The role of an accountant on a mine site has evolved significantly over the past ten to 15 years.

The most senior finance position held at a mine site is ordinarily that of a commercial or business manager, who is an integral member of the site management team, playing a key role in providing commercial input and business support to improve business performance. The commercial or business manager supports the general manager of site operations in leading business planning, analysis, cost enhancement and efficiency, as well as supporting business improvement and development projects. The role ensures appropriate business

governance on site, optimisation of business processes on site and that sound business decisions are made and associated actions are taken that ultimately result in improved business and financial outcomes.

8.3.2 Accountability and responsibility

The breadth of the commercial or business manager role at a site requires a multi-disciplinary set of skills as this role is often responsible for accounting, coordination of site audits, supply chain management, contractor management, business strategy and planning, business analysis, business case evaluations, financial modelling and management of delivery of information technology at the site-based level. The role may also have accountability for camp administration and site travel management. In addition, as a senior member of the site management team, experience in the leadership and management of people is critical to success in this role.

A mine accountant provides financial and/or management accounting services to the site commercial department. This requires technical knowledge and the ability to apply accounting standards, which in Australia are based on International Financial Reporting Standards. This may also require the application of the accounting policies adopted by a foreign parent, which may be subject to the USA Generally Accepted Accounting Principles (USGAAP) or other standards. The mine accountant is responsible for the financial process adopted at each month-end and the preparation of monthly, quarterly, half-yearly and annual financial and management reports.

The key elements of mine accounting include:

- recording of accruals
- inventory measurement and accounting
- accounting for stores and consumables
- assisting in the preparation of applications for expenditure on capital items, major projects, etc
- recording of additions, disposals and transfers of property, plant and equipment
- accounting for mine property and development
- accounting for provisions for employees
- accounting for provisions for mine rehabilitation and restoration
- allocation of costs between inventories of raw materials (ore), work in process, finished goods and stocks in transit
- reconciliation of accounts, including inter-company reconciliations with trading partners
- maintenance of fixed asset registers (for accounting, tax and insurance purposes)
- maintenance of general ledgers
- performance reporting and analysis – monthly, quarterly, annually
- preparing forecasts – cash and profit – for quarter/year in advance.

8.3.3 Managing the relationship between site and corporate

Effective delivery of mine accounting and related services to a site requires the establishment of clear lines of accountability and responsibility for completion of critical tasks in the process. Often these are provided in service level agreement (SLA) between the site and the corporate business unit responsible for delivery of services to the site.

Mine accounting services can be performed at a site or can be delivered by a shared business services team located at a corporate head office or dedicated off-site facility. More and more companies are reviewing their financial accounting processes and determining some or all of these can be performed more cost effectively and efficiently from a centralised shared business service that is established to provide timely, accurate and reliable information to a site(s).

Irrespective of where the mine accounting function is based, it is critical that the mine accountants build a good relationship with site and corporate functions to ensure the success of an SLA. Where the mine accounting functions are provided from a centralised shared service, this requires strong planning, communications and management skills to ensure the mine accountants understand the organisation and the drivers of cost and performance. Equally it is important for the mine accountants to ensure site-based finance and commercial functions are appropriately informed of the financial outcomes from operations. A key challenge in such an environment is the development of a 'shadow' finance function being built at sites where their needs are not being met or the site business requirements exceed the services delivered by the centralised shared services functions.

8.3.4 Financial accounting

The accounting rules required to be adopted by mining operations are set out in the International Financial Reporting Standards (IFRS) issued by the International Accounting Standards Board (IASB) and adopted by the Australian Accounting Standards Board (AASB). Table 8.3.1 provides a list of major standards that mine accountants are generally required to apply in relation an operating mine site. This list excludes areas such as accounting income tax and financial instruments, eg hedging, which are ordinarily managed at a group level by a corporate accounting function.

TABLE 8.3.1

Major accounting standards impacting exploration projects, development projects and operating mines.

Accounting issues	Australian Accounting Standard
Accounting for drilling, assay and associated costs of exploration for minerals and evaluation of minerals	AASB 6 Exploration for and Evaluation of Mineral Resources
Accounting for inventories of ore, work in progress, finished goods (concentrate and metal) and stocks in transit	AASB 102 Inventories
Accounting for by-products produced	AASB 102 Inventories
Accounting for stores and consumables used in the mining, production, processing and storage of inventories	AASB 102 Inventories
Accounting for mine property, mine development (including waste removed to access ore), plant and equipment used in mining, milling, processing and transportation of products	AASB 116 Property, Plant and Equipment
Accounting for mining rights and goodwill associated with the acquisition of businesses and entities	AASB 138 Intangible Assets
Accounting for contributions from jointly controlled entities (JCE), jointly controlled operations (unincorporated joint ventures) and jointly controlled assets	AASB 131 Interests in Joint Ventures
Accounting for environmental issues and liabilities associated with mine site remediation, restoration and dismantling of milling and processing facilities	AASB 137 Provisions, Contingent Liabilities and Contingent Assets
Accounting for revenue from the sale of product, including rules on recognition of revenue from shipment	AASB 118 Revenue

In determining how to apply the above accounting standards, mine accountants must be able to interpret and apply 'group' accounting policies and judgement in considering the specific facts and circumstances applicable in each situation. One of the key challenges faced by a mine accountant from a financial accounting perspective is determining whether expenditure is capitalised or expensed. This decision requires technical application of the abovementioned accounting standards, judgement by the mine accountant and consultation with site personnel (including the site commercial/business manager), corporate accountants and the organisation's external auditors.

Mine accountants must consider whether the amounts spent will create an asset that provides future economic benefits, either through their use and/or subsequent sale, over a period of more than one year. A threshold such as \$1000 may be set as the minimum level for the capitalisation of an asset.

Having capitalised an asset, the mine accountant must determine when the asset is available for use to commence depreciation, the life of the asset over which it must be depreciated and the method used to depreciate the asset. Many mining companies elect to depreciate their mining and milling/processing assets using the 'units of use' method. This method results in an asset being depreciated over the life-of-mine based on production as a percentage of the mine's Resources and Reserves.

8.3.5 Management accounting

REPORTING OF MINING AND MILLING COSTS

Invariably, mining operations capture and report their costs in one of two ways – based on the nature of the costs (eg salaries and wages, consulting fees, external contractors, etc) or their function (eg mining, milling, processing and general administration).

The presentation of this information is dependent upon, amongst other things:

- the chart of accounts structure adopted by the organisation
- the use of cost centres and/or general ledger account structures
- the recipients of the report, ie mine, corporate or executive management
- legal, regulatory or other requirements.

Accordingly, establishing business definitions of key data points is critical to enable the extraction and presentation of relevant information for reporting.

Figure 8.3.1 identifies the key activities involved in converting resources to metal available for sale, and points through the operating cycle where costs should be captured and measured for management reporting purposes.

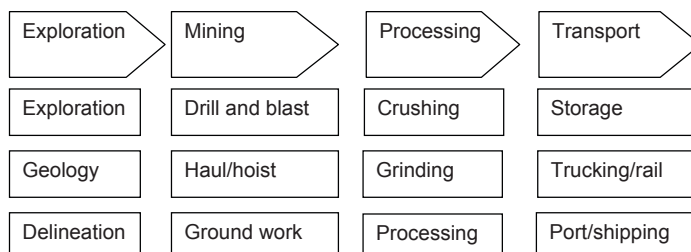


FIG 8.3.1 - Mining and milling operational view.

8.3.6 Benchmarking of costs reported by mines

The costs of a mine are ordinarily separated into operating and non-operating costs, such as corporate overheads recharged to the mine. These can be further separated into direct cash costs, indirect cash costs and non-cash costs (such as depreciation, depletion and amortisation).

A common methodology applied by mines for comparison between companies is the Brook Hunt methodology, which is summarised below.

Direct cash costs (C1) are the cash costs for:

- mining
- on-site processing (costs of milling, concentrating, leaching, solvent extraction or electrowinning)
- on-site administration and general expenses (G&A)
- any off-site services that are essential to the operation
- smelting (including toll smelting charges if applicable)
- refining (including toll refining charges if applicable)
- concentrate freight costs
- property taxes and severance taxes
- marketing costs.

Indirect cash costs are the costs for:

- corporate overhead allocation (head office costs)
- research and exploration attributable to the mining operation
- royalties and 'front-end' taxes (including sales tax, export tax and duties, plus any other revenue-based taxes, but excluding all income and profit taxes and value-added taxes)
- extraordinary items (eg strike costs, shortfalls in pension funding).

Non-cash costs are the costs for:

- depreciation, amortisation and depletion
- write-down of assets
- deferred stripping, or leaching, charged back to an operation after capitalisation of direct cash costs in previous years.

Capitalised cash costs are direct cash costs that are capitalised:

- mine development
- deferred waste stripping or leaching costs.

C1 cost is the *net direct cash* cost necessarily incurred from mining through to refined metal, less, for normal costing net by-product credits.

C2 cost is C1 cost, plus depreciation.

C3 cost is C2 cost, plus interest and indirect costs.

The *total cash* cost is the sum of direct costs, indirect cash costs and interest charges. Non-cash indirect costs are not included.

Whilst C1, C2 and C3 are commonly used to benchmark comparison of costs of production across the mining sector, these measures are not acceptable for financial or management accounting requirements to measure the cost of inventories. Hence, the unit cost of

production used by most mining companies does not equate with their C1 costs, as the unit cost of production ordinarily includes an allocation of overheads, depreciation, depletion and amortisation, and does not include the benefits of by-product credits.

8.3.7 Reporting the performance of the mine

The format adopted to report the operating results of a mine should include physical statistical data, such as sales and production, as well as financial information, such as sales, costs from each part of the mining process, and overheads. Such analysis should include actual, budget and, where available, the most recent forecast data.

An illustrative example of reporting the performance of a mine site is presented in Table 8.3.2. This table reflects the nature of activities performed at a mine. An alternative presentation would be to reflect costs by their type, ie salaries and wages, energy, materials, depreciation and amortisation, etc. Mine accountants need to be able to view costs from both perspectives to be able to explain the reasons for variances from budget.

It is also pertinent to note that for management reporting purposes the main focus of variance analysis is to explain variations between actual and budget, whereas for external financial reporting purposes, analysis is required of the variations between current year and prior years.

TABLE 8.3.2
Monthly mine report.

Month			Year to date			Full year
Actual	Budget	Variance	Actual	Budget	Variance	Forecast
			Production (t)			
			Recovery (%)			
			Sales (t)			
			Sales			
			Less freight costs			
			Net sales			
			Operating costs			
			Mining			
			Milling/processing			
			Transport			
			Other			
			Operating costs			
			Other operating costs			
			Exploration			
			General administration			
			Other			
			Total non-operating costs			
			Total costs			
			Net profit before interest and taxes			

8.3.8 Other mine site reporting

The range of reports a mine site accountant or commercial manager would be required to contribute to and/or prepare are as listed below.

Daily reports:

- production report, showing
 - mine physicals for development, trucking and ore stocks
 - mill/processing plant physicals for run time (hours) feed grades (per cent) recovery (per cent) and production grade (per cent)
- safety reporting – incidents and hazards reported for the day earlier.

Weekly reports:

- production reports as above
- report on critical production, planning, safety or operational issues for the coming week
- revenue and/or cash-flow forecasts.

Monthly reports:

- flash report showing monthly performance in financials and physicals
- capital expenditure report – showing actual spend, committed spend and forecast spend against budget/forecast
- monthly site operation report providing commentary on results, including analysis of revenue, costs, cash flow and capital expenditure – the mechanism for delivery, format and style of such reports will vary depending on organisation/site-specific KPIs, reporting packages, etc
- detailed mine and mill/processing plant physicals reports
- assay/surveyor reports
- safety, health, environment and community (SHEC) reports.

Quarterly reports:

- quarterly production, statistics and operating performance
- royalty returns.

Annual reports:

- financial – eg profit and loss, balance sheet, cash flows
- production – physical units produced, sold; grade; recovery rates.

CHAPTER 9

MINERALS AND MARKETS

Sponsored by:

Alkane is an Australian Stock Exchange listed multi-commodity explorer and miner focused in the central west region of New South Wales, and has been in existence since 1969.

The company developed the Peak Hill Gold Mine, near Parkes in 1996, which it operated until 2005. The funds generated from this operation were directed back into the region, leading to further discoveries and planned developments. Alkane currently has two advanced projects in progress for development near Dubbo. The Tomingley Gold Project is anticipated to be in production mid-2013 producing 50 000 - 60 000 oz of gold per year.

The Dubbo Zirconia Project is a major resource of zirconium, niobium and rare earth metals and an innovative process has been developed to extract these metals into a marketable form suitable for use in many expanding applications, such as electronics, advanced ceramics, magnets, batteries, phosphors and speciality glasses. The project is in the final stages of feasibility and a development decision is scheduled in the second half of 2013.

The company also maintains an active exploration program in the region and has been very successful in producing a consistent stream of new discoveries, which will flow in to the project development pipeline. This program resulted in the discovery of a major gold deposit near Orange in partnership with the United States gold company, Newmont.

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9.1 INTRODUCTION

It will come as little surprise that the Australian mining industry is a major contributor to the national economy. The export revenues from the various metals and minerals mined in Australia are very large indeed.

Table 9.1.1 lists the largest Australian commodity markets ranked in order of export revenue. The Australian Bureau of Agriculture and Resource Economics (ABARE), estimates 2011-12 Australian export revenues as follows by commodity (values cited in Australian dollar currency).

TABLE 9.1.1
Largest Australian commodity markets ranked in order of export revenue.

Commodity	A\$ (Billion)
Iron ore and pellets	65.3
Metallurgical coal	41.7
Thermal coal	18.3
Gold	18.1
Crude oil	13.8
Copper	10.3
Liquefied natural gas	10.0
Alumina	7.1
Aluminium	4.5
Nickel	4.5
Zinc	3.1

2011-12 represents an example of the continued strength in economic conditions for Australian minerals and energy exports. The paragraph below synthesises the Australian government perspective (ABARES, 2011):

Export earnings for Australian mineral and energy commodities are forecast to be around A\$218.3 billion in 2011-12, compared with an expected A\$182 billion in 2010-11. The value of energy exports is forecast to rise by 24.7 per cent to A\$88.6 billion in 2011-12, reflecting forecast higher prices and export volumes for coal. For metals and other minerals, export earnings are forecast to rise by 16.9 per cent to A\$129.7 billion in 2011-12.

To further emphasise the importance of minerals and mining to Australia's economy, mining accounts for approximately eight per cent of Australia's gross domestic product (GDP). Mining also provides a number of other economic and social benefits.

Here is the assessment of positive socio-economic impacts from the mining sector as compiled by the Association of Mining and Exploration Companies (see AMEC, 2011). The Australian mining sector contributes as follows:

- approximately 50 per cent of Australia's exports
- providing jobs (approximately 160 000 in direct employment, and over 500 000 in indirect employment in hundreds of service industries)

- state/territory and federal government revenue (over A\$21 B in state/territory and federal taxes, including A\$7 B in royalty payments)
- new project development
- rural, regional and community development
- public and private infrastructure (roads, railways, ports, power, accommodation)
- education and training (including indigenous partnerships)
- financial and other support to a large number of charitable, welfare, community and sporting organisations
- technology innovation
- research and development
- environmental protection and biodiversity conservation initiatives
- environmental research and data collection of threatened, protected and previously unidentified species of flora and fauna
- Aboriginal cultural heritage protection
- native title and cultural heritage payments to traditional owners, communities and stakeholders.

9.2 MINERAL ECONOMICS

Mineral economics is the ‘application of economics in the study of all aspects of the mineral sector’ (MacKenzie, 1987). As such, it is the overarching subject area to the informal term ‘minerals and markets’. Mineral economics can be regarded as one small part of the overall discipline of economics, defined by Waud *et al* (1996) as follows:

Economics is the study of how people and society choose to employ scarce productive resources to produce goods and services and distribute them amongst various groups in society.

The division of economics into the fields of microeconomics and macroeconomics is pertinent also.

Microeconomics is the study of economic decision-making by consumers, households, firms and government, and the way in which these relate to the operation of markets (Maxwell, 2006). Its focus has been on areas such as supply and demand, on the organisation of markets and on industry regulation.

Conversely, macroeconomics is concerned with the operations of national economies and the world economy (Maxwell, 2006). Its focus has been on measures of economic performance such as GDP, inflation, investment, saving, economic growth, the balance of payments and the distribution of income and wealth. It is concerned as well with the formulation of fiscal, monetary and other areas of national economic policy to manage these variables.

In this chapter, the bias is towards microeconomics over macroeconomics, given that an understanding of the industry economics forces that interact to determine a mineral’s price are of immediate importance to mine managers.

We have chosen to cover a high-level synthesis of mineral demand, mineral supply – and then outline the key attributes of individual mineral markets. A single chapter on mineral economics of course cannot be comprehensive in its scope. Readers are therefore referred to the books by Crowson (1998), Rudenno (2009), Trench (2011) and to AusIMM

Monograph 24 *Australian Mineral Economics* (Maxwell and Gui, 2006) for more in-depth and broader discussion on aspects of mineral economics not covered in this handbook.

9.2.1 Mineral demand

Forming a view on the demand-side outlook for mineral commodities is an important issue facing mineral resources organisations. At the extreme, if a organisation searches for and develops a mineral resource for which there is limited or diminishing demand, the future profitability of a mine – and indeed the entire organisation – can be placed at risk.

This section provides an overview of mineral demand. The commodity profiles that follow then provide detail on aspects of demand (and supply) for each mineral commodity.

First to the high-level forces at work in driving mineral demand (Tilton, 1985): microeconomic analysis recognises that demand and price are strongly inter-linked. The demand for a particular commodity is a function of its own price, with higher mineral prices meaning lower mineral demand. Conversely, lower price means higher demand. These facts hold true whether the particular commodity price is set on a metals exchange (such as for copper, aluminium and nickel) or determined by contract negotiation between buyers and sellers (as for iron ore, coal and mineral sand products such as zircon and rutile). Put simply, consumers of minerals are price-sensitive. When prices are lower they will buy more – leading eventually to a rising price of course. A related economic concept here is that of the elasticity of demand, that is, how percentage shifts in price reflect percentage shifts in consumption.

Besides the prevailing commodity price, the next key force driving mineral demand is the strength of the economy itself, with GDP the typical high-level measure of health. Demand for many minerals grows as economies grow – that is as GDP and as industrial production (IP, one constituent of GDP) rises. Take nickel, copper, zinc or the steel alloying metals as examples. Demand in these markets rises as world economic growth rises. Conversely, demand for these metals is curtailed by the threat of sustained economic recession. Demand shocks negatively impact commodity prices in the short-run more often than does over-supply (and with negative demand shocks the impact is quicker too). The intensity of metal use by economies is also important. Expanding economies, most notably developing economies such as India and China, are investing in capital goods, which are highly metals intensive. Conversely, stable and more mature economies, such as in Europe, Japan and the United States, have a relatively higher proportion of their economic output in service industries – and therefore incremental consumption growth in these economies generally has a lower metal intensity.

Next on the list of forces controlling demand for a given mineral is the price of substitutes. The logic here is straightforward: when one mineral commodity or metal gets too expensive, the rational economic decision for consumers can be to switch to an alternative. Copper and aluminium substitute for each other in several end-use applications for example. Substitutes need not be limited to other metals of course. Plastics and ceramics also become substitutes when metal prices are at historical highs.

Changes in technology also make for changes in mineral prices – with this force of particular influence amongst the minor metals for which supply may be limited and tight. However, whilst new technological uses can influence consumption patterns, particularly in minor metals as stated, the relative size of the new demand segment compared to traditional uses is the real test of whether the new use will generate real price impact.

There are two other significant forces at work. These are firstly that purchasing patterns make a difference. Compared to actual price and economics strength, purchasing patterns lies down the list – but nevertheless can be important. For example, the Indian wedding season has a seasonal impact upon gold demand. The season runs from late September to December each year and leads to increased gold buying in those months. On the negative side, the fact that metal processing plants (and car manufacturers) close during the European and North American August ritual vacations dampens metal demand across a whole suite of metals in July-August.

Not least when it comes to mineral demand comes the role of government. Government spending, meaning expansionary economic policy across the world's major economies, for whatever reason, can have a positive impact upon minerals and metals prices. The effects of government policy on the demand-side of the equation are more likely seen in the base metals and bulk commodities rather than in precious metals.

9.2.2 Mineral supply

As for mineral demand, there are a number of fundamental forces at work that act in concert to determine the level of mineral supply at a given time – and the incentive to supply into the market in the future.

A mineral's price is of paramount importance – and hence a major determinant of supply. When commodity prices rise, more new production is commissioned and hence supplies increase. In practice of course, there may be other impediments that prevent a rapid supply response to higher prices. Conversely, falling prices for a particular commodity lead to the closure of mines producing that commodity. Again of course, this is a simplification. As one can imagine, producers are reluctant to immediately close mines when prices decline below production costs, not least because of the significant mine closure costs.

So we might describe the supply responses to both rising and falling commodity prices as 'sticky' – meaning that it takes time to both bring new production into the market (when prices rise) and can take time for supply to exit the market when prices fall – as decisions to close mines are not taken lightly. Of course, supply responds not only to price itself, but also to expectations of future prices, so the mineral supply-to-price function is not entirely explained by the spot prices prevailing at a given time.

Second on the list of forces that dictate mineral supply is the influence of input costs. Actual costs of production are critical to determine the aggregate level of supply; in particular the costs of the higher cost producers that will either continue to produce, enhance production, or curtail production in response to the interplay between their costs and prevailing prices. A typical list of costs includes for example energy costs, labour costs and the price of the chemicals and consumables used in mineral processing. The relative importance of each cost centre varies according to the type of metal being produced and the deposit-style and specific characteristics of the mine.

Technological change also influences the supply of minerals – in addition to being important on the demand side of the equation. Advances in processing techniques driven by technological improvements can lower the average production cost for minerals. Critically, however, it is the take-up of technologies and impact of supply-side technological improvement on marginal (high-cost) mines that is most important. Technological improvement on the supply-side can therefore have the knock-on negative effect of reducing commodity prices – in particular if the improvements are made at high cost mines. One simple example is the year-in-year increase in the size of trucks operating at large open pit mines.

As the truck size increases, so the cost per tonne to move ore (and waste) falls, lessening the cost of supply. As prices are (in theory) controlled by the point at which supply volumes tracing out the supply curve intersect with the demand curve then equilibrium prices will fall as a result. If the take-up of technology is not uniform, however – and as a result prices remain unaffected – then those organisations that adopt new technologies benefit over and above those that do not. The rise of ‘mini-mills’ furnaces in the steel industry is one example. Solvent extraction electrowinning technology (SX-EW) in copper is another. Technological changes take time to fine-tune of course – and for some years new technologies can actually act to raise production costs unexpectedly above the planned costs. Pressure acid leach technologies in nickel processing are a good example from recent years of this effect.

Mineral supply is also impacted by labour strikes, particularly for those metals where production is concentrated amongst either a few producers or a few countries. In copper for example, Chile, the world’s largest producer, has been prone to strikes that have impacted supply on several occasions. When strikes occur, the copper price rises. Indeed, the effect of strikes is in a positive feedback loop when it comes to its impact upon prices. That is, workers are prone to strike when prices are high (as they may take the view that the organisation, not the workforce, is benefiting most from the price rise). Already high prices are then pushed even higher on those occasions when strikes occur.

Market structure is the next force at work in the determination of mineral supply. Most readers would be aware that many mines contain more than one payable mineral. They have a main product, but perhaps also one or more by-products that returns additional revenue credits to the mine owner. BHP Billiton’s giant Olympic Dam mine in South Australia is a good case in point. Revenue at Olympic dam comes from not only copper and uranium, but also from gold and silver.

The amount of metal produced as a main product versus the amount produced as by-product and co-product is important. Metals with significant by-product production tend to respond less to changes in the supply-demand balance. Production of by-product metals tends to continue regardless – even if prices fall – as the mine economics are driven by the main product not the by-product. Price extremes (both low and high) in by-product markets can result. Examples include molybdenum (a by-product at several large copper mines), silver (a by-product at lead-zinc mines) and cobalt (a by-product of some nickel and copper mines).

Scrap supply (otherwise known as secondary supply) also influences commodity prices. Scrap can simply be thought of as another ‘mine’, which increases production when prices rise and pulls back upon production at times when prices are low. As such, one can conceptualise scrap production as a form of ‘swing’ producer in the market for a metal. Examples of scrap supply exist for all the major metals markets. In gold, for example, the rise in prices of the yellow metal over recent years has prompted traders to seek out additional scrap supply (which they aim to buy at a discount to actual prices and then pocket the difference). Another interesting example of scrap is in the uranium market. Here secondary supply is sourced from the drawdown and re-processing of former military stocks of uranium.

Finally, as with most economic activities, the government has a role to play in determining mineral supply. Those exploration companies that switched focus from their Australian coal and iron ore prospects in favour of overseas prospects when the Australian Federal government flagged increased taxes on coal and iron ore production from 2012 is a recent example of the impact of government legislation upon supply – in this instance curtailing likely future supply from Australia – and potentially increasing overseas supply.

9.2.3 The role of commodity investors

Had this chapter been written a decade ago, the discussion of what drives commodity prices would have stopped following the above sections on demand and then supply. The interface between the two market mega-forces results in either a scarcity of metal, else significant stocks and inventories that act to buffer changes on either side of the supply-demand equation.

In the last decade, however, a third force has come to the fore: that of commodity-focused investors. Financial players in the markets act on the demand side. They buy physical metal for investment or speculative purposes and hold it – removing it from general circulation – and hence pushing up prices. The physical metal still exists of course – so investor-sourced commodity demand is not actual metal consumption – that point should be remembered should market conditions move to a point where such metal stocks are sold into the market.

The area in which commodity investors are most evolved is in precious metals. Exchange-traded-funds (ETFs) that offer tradable securities backed by physical metal are now well established both in gold and silver. In many respects, ETFs in gold can be viewed as an extension of the central banks – who hold gold reserves for the long term.

Commodity investor influence on prices is not limited to gold and silver however. In the base metals too, in particular the large London Metal Exchange (LME) contracts of aluminium and copper, the presence of investors clearly influences prices.

9.3 INDIVIDUAL MINERAL MARKETS

There are a number of groupings under which individual mineral markets could be summarised. In this chapter markets have been grouped under the headings of bulk minerals commodities, base metals, precious metals and diamonds and finally speciality minerals and industrial minerals.

This nomenclature is not a formal one. Other classifications could have been chosen such as steel raw materials for example, which would group some markets classified here as bulk markets (iron ore, coking coal, manganese) together with others cited here within the base metals (nickel) and so on.

9.3.1 Bulk minerals commodities

In this section, the key attributes of the coking coal, iron ore, manganese, phosphate and thermal coal mineral markets are briefly outlined.

COKING COAL

Coking coal is the purest form of coal (high carbon component), which enables it to act as a reducing agent (after conversion to coke) in pyrometallurgical processes such as smelting.

Demand

Coking coal is a vital input to the world steel industry. As such, those countries with large steel industries are high on the list of consumers. These include China, Japan, the United States, Russia, India, South Korea and Germany. China is seen as the major growth market, in particular the coastal provinces where the greatest existing steel capacity and capacity growth are focused. Steel consumption growth in China is tied to the continuing urbanisation trend with the requisite infrastructure needs and build-out.

Market and pricing

Coal prices are agreed by contract, with contract terms reflecting coal quality, along with subordinate adjustments relating to the likes of delivery schedule and volume. Hard coking coal prices (usually cited as free on board, fob) per tonne.

Benchmark coal prices for standard coal quality are reported by market analysts and organisations. In 2010, the frequency of contract price agreement changed from an annual contract to quarterly contracts, with the BHP Billiton–Mitsubishi Alliance (BMA), who produce coal from the Saraji and Peak Downs operations (amongst others) leading the change. It is anticipated that a continued shift towards shorter term contracts will occur over time.

Higher coal contract prices are favoured by low ash contents, higher-strength coals, higher carbon content and calorific value, low moisture content and low impurities (volatile matter, sulfur and phosphorus).

Supply

Coking coal operations in Australia are owned by a number of Australian Stock Exchange (ASX)-listed and overseas-listed companies. Amongst the major international diversified miners, BHP Billiton, Xstrata, Anglo American, Vale and Rio Tinto all control Australian coal mines. Indeed, BHP Billiton is the world's largest metallurgical coal exporter. ASX-listed diversified conglomerate Wesfarmers also has coking coal exposure through its interest in the Curragh coal mine. Below the majors, however, there are also a number of coal-focused mid-tier organisations. Overseas, the main coking coal producers include Cliffs Natural Resources, Alpha Natural Resources, Consol Energy, Foundation Coal Holdings Walter Energy, Massey Energy, Patriot Coal and Arch Coal (all United States), Teck Coal, Grande Cache Coal Corporation and Western Canadian Coal Corporation (Canada) and Mechel, Raskadskaya and Severstal (Russia). Given that mergers and acquisitions are ongoing in the coking coal sector, as for other sectors, individual organisation names may change over time as a result – albeit the long-life operating mines remain.

Geology

Coals are the geological remnants of the past vegetation and forests that covered continents in their geological history. In the process of lithification of the plant remains into rocks, chemical changes result, with hydrogen and oxygen being driven off from the rock composition thereby increasing the overall carbon content in the coal.

Key countries of supply

Australia is the world's largest seaborne exporter of coking coal. The United States and Canada are also significant exporters. Other producers include Russia, the Czech Republic, Mongolia, China, New Zealand, Indonesia, Venezuela, Columbia, Bangladesh, Mozambique, Poland, South Africa and Ukraine.

Grades

Coals are classified depending upon their carbon content as follows: lignite 45 - 65 per cent carbon; semi-bituminous 60 - 75 per cent carbon, bituminous 75 - 90 per cent carbon, semi-anthracite 90 - 93 per cent carbon and anthracite 93 - 95 per cent carbon. Generally, metallurgical coal has less than one per cent sulfur and less than eight per cent ash. Most premium metallurgical coal is low- to medium-volatile bituminous coal.

A key aspect of coal seam analysis is to assess calorific value (CV), measured in kilocalories per kilogram (Kcal/kg). Results range from 2000 Kcal/kg for lignites and brown coal to over 8000 Kcal/kg for some bituminous coals and anthracite.

Mineral processing

Coal is sold directly to customers after washing and heavy media separation to remove ash, fines and waste rock.

IRON ORE

Demand

Iron ore demand is directly linked to the fortunes of the global steel industry as a steel raw material. China's urbanisation has been one of the major macro-trends driving steel consumption growth, with demand growth in China outpacing other economies.

China's imports of iron ore have increased rapidly in the 21st century, at a time when international trade of iron ore elsewhere across the world has remained relatively flat. From only around 50 Mt per annum a decade ago, China now imports over 400 Mt of iron ore per annum. China's steel sector produces metal for the building and construction sector (which constitutes over half total consumption), machinery, automobiles and home appliances in addition to specific market segments such as shipping and rail. The main producers of steel globally are led by Arcelor Mittal (a global company now operating in over 50 countries) with other major companies including Baosteel and Jiangsu Shagang (China), POSCO (Korea), Nippon Steel and JFE Steel (Japan) and Tata Steel (India).

Market and pricing

Sales take place under negotiated contract term agreements and/or via spot cargo markets. Spot contract prices are more volatile than term contracts, with the Chinese import price for Indian fines (62 per cent Fe) regarded as indicative of the spot market.

Hematite ores from Western Australia are sold as either lump or fines. Lump ore is typically run-of-mine material with a size range between 6 mm and 30 mm. Fine ore is below this size range. Magnetite ores (and some hematite fines) are converted to pellet form for sale. Pellets are typically 16 to 20 mm in diameter.

A premium is payable for high grade ores and for those ores with low levels of impurities. Impurities include sulfur, phosphorus, alumina and silica.

Supply

Global trade in iron ore is dominated by a few large companies – although smaller fringe players continue to enter the sector – a trend that is expected to continue. BHP Billiton is due to export approaching 150 Mt iron in 2011 from Australia. This figure matches that of Rio Tinto, who will approach the same 150 Mt benchmark to be exported from their Hamersley operations in 2011. Additionally, Rio Tinto exports a further 60 Mt from their Robe River operations, also in the Pilbara. Fortescue Metals Group (FMG) is the next largest Australian exporter ramping up towards 50 Mt production in 2011, once again from the Pilbara region. Overseas, Brazil's Vale is the largest iron ore exporter at around 250 Mt/a. China supplies its steel sector from Chinese domestic supply in addition to imported iron ore. Like imports to China, domestic iron ore production has increased sharply over the last decade; however, the grade of China's domestic mines is considerably lower than imported iron ore at typically only 30 per cent iron.

Geology

The main ores of iron are magnetite (Fe_3O_4), hematite (Fe_2O_3) and goethite ($\text{Fe}_2\text{O}_3\text{H}_2\text{O}$).

Key countries of supply

Australia, Brazil, Canada, India, China, South Africa.

Grades

Lump and fine ores from the benchmark Rio Tinto and BHP Billiton operations of the Pilbara grade in the range 62 to 65 per cent iron. Recent mid-tier entrants to the iron ore industry are mining and selling ores with grades below 60 per cent iron, typically 57 - 58 per cent Fe.

Mineral processing

Hematite iron ore requires only physical sorting for sale. Ore is then used by consumers in the fabrication of steel whereby iron ore is fed into a blast furnace, mixed with preheated coke and air to recover pig iron. Pig iron is then upgraded to various steel classifications in an oxygen converter.

MANGANESE

Demand

Manganese is the fourth most commonly used metal after iron, aluminium and copper. Manganese end-use is almost entirely as a constituent of alloys, especially in the steel industry, where the principal feedstock is ferromanganese. In total, various steel uses comprise over 90 per cent of manganese demand. Geographically, China dominates end-user demand at approaching 50 per cent of the global market. Other major consumers include Japan, Europe, the US, the Middle East and India.

Market and pricing

Various forms of manganese are traded. Ores for the steel industry are typically more than 40 per cent manganese, and have high manganese to iron ratio above 4:1. The market is denominated in price per dry metric ton unit where one unit relates to one per cent manganese per dry metric ton (similar to iron ore pricing). The main types of downstream processed product are electrolytic manganese (99.7 - 99.9 per cent Mn), ferromanganese (80 per cent Mn, 20 per cent Fe) and silicomanganese (80 per cent Mn, 20 per cent Si).

Manganese ore prices are negotiated by buyers and sellers – there is no exchange trade. Indicative prices for manganese flake are available at the Metal Pages web site. Price premiums available for products that suit individual customer needs and where impurities are minimal. Capped iron, silica, phosphorus and alumina contents are key price differentiators. Contracts can be annual, quarterly and spot. International benchmark pricing (similar to iron ore) has been the traditional pricing mechanism and reference for transactions. Japanese smelters as the buyers and BHP Billiton as the manganese seller have traditionally acted as the pricing benchmark.

Supply

The total mine output globally is around 40 Mt of ex-mine manganese product. Manganese suppliers are fairly concentrated – meaning there aren't too many of them. Not surprisingly, they'd like to keep it that way. So the likes of BHP Billiton, Brazil's Vale and Anglo American

are looking to incremental expansions at their operations to curb the attractiveness of opportunities in the industry for new entrants. The scarcity of high-grade material also acts as a barrier to entry to premium markets. Manganese is not recycled.

Geology

The principal manganese ores are pyrolusite, braunite and hausmanite. Most economic manganese deposits are hosted within sedimentary rocks. Sedimentary manganese deposits of Archaean age occur in Brazil, Guyana, Cote D'Ivoire, Ghana and Burkina Faso. The upper caps of these deposits are of higher grade as supergene processes have enriched the ore. Proterozoic age carbonate-associated manganese deposits occur in the Kalahari region of South Africa, in Brazil and in Columbia. The manganese ores at Groote Eylandt in Australia are again sedimentary, being pisolitic akin to certain iron ore deposits. Manganese nodules occur on the ocean floors; however, to date they have not been exploited commercially.

Key countries of supply

China, South Africa, Australia, Gabon, Brazil, Ukraine, India, Morocco. South Africa is definitely in the industry for the long haul, with around 80 per cent of the world's known in-ground resources, the focus being the world-class Kalahari Basin manganese deposits.

Grades

Mining is invariably via open pit methods. High-grade comes in around 45 - 50+ per cent Mn. For example, the Woodie Woodie mine in Western Australia produces lump ore that typically achieves 49.5 per cent Mn. By comparison, although the Chinese are a major producer, the average Chinese mine grade sits only around 30 per cent. OM Holdings' (OMH) run-of-mine grade at its Bootu Creek mine in the Northern Territory is around the reserve grade of 22 per cent Mn. However, OMH sells a beneficiated ex-mine Mn produce at around 36 per cent Mn after on-site sorting.

Mineral processing

Manganese ore can be beneficiated at the mine site to raise the grade of the ex-mine manganese product and to remove undesirable impurities. Parallels to iron ore beneficiation apply. That is, lump ore (>6 mm) and fine product (<6 mm) are differentiated. Lump product is generally smelted whereas fine product can be used as feed for chemical or electrolytic processing.

Manganese ores are then smelted to produce ferromanganese, silicomanganese and ferromanganese-silicon (65 - 68 per cent Mn). Ferromanganese production occurs in both blast furnaces and electric arc furnaces (EAFs). Slag from ferromanganese production is used as a feedstock to silicomanganese production.

PHOSPHATE

Demand

Phosphorus is one of the three major nutrients required for plant growth, alongside nitrogen and potassium. The world market for rock phosphate sits at around 170 Mt with use in fertilisers accounting for close to 90 per cent of total demand. Fertilisers are essential to increase the yield of agricultural land. Demand is global with most countries being phosphate consumers. Western Europe and India stand out as large importers of phosphate

rock. A strong consumption outlook is underpinned by global population growth, by changing diets and increasing wealth in the developing world, demand from biofuels and the urbanisation of China increasing protein demand. In the developed world, fertiliser cost is a small ingredient in the total cost function of grain production.

Market and pricing

International trade in P_2O_5 is not generally by direct shipment from the producer to the end-user farmers. There are several market players in between including the international brokers and traders, large regional distributors and local dealers. Historically, prices for phosphate rocks were stable at around US\$50/t. A shortage of rock in 2008, however, pushed up prices ten-fold with high-quality rock sales touching US\$500/t. The impact of the global financial crisis (GFC) then saw prices fall to around the US\$100/t level before gradual increase in 2010-11.

Supply

Most phosphorus is obtained from mining phosphate rock. Incitec Pivot (IPL) is the incumbent producer in Australia. Agrium and Mosaic are major North American producers. The World Phosphate Institute (IMPHOS) is comprised from a network of producer companies operating in key countries: Specifically these are CPG/GCT (Tunisia), FERPHOS (Algeria), ICS (Senegal), JPMC (Jordan), OCP/PHOSBOUCRAA (Morocco) and IFG (Togo).

Geology

Phosphorus does not occur as a free element, but as phosphate compounds. Phosphate rock is a type of sedimentary rock enriched in P_2O_5 by the presence of the mineral apatite. Sedimentary phosphate deposits occur throughout the geological time scale and most were formed in offshore marine conditions on continental shelves. Sedimentary phosphate rocks have a wide range of chemical compositions and great variations in physical forms.

Key countries of supply

Significant phosphate rock supply is concentrated in a few countries and with few suppliers. Additionally, however, a number of small mines lengthen the full list of countries who undertake supply. Producers include Morocco, Tunisia, China, United States, Algeria, Brazil, Israel, Jordan, Kazakhstan, Uzbekistan, Russia, Finland, South Africa and Egypt. Historically, phosphate rock was also mined from the Pacific island of Nauru.

Grades

Typical production grades for phosphate rock are 29 - 30 per cent P_2O_5 . The long-term average grade of mined rock has been falling, with producers shifting to lower grade deposits.

Mineral processing

Mining is typically by open pit method. The presence or otherwise of contaminant minerals impacts upon ease of processing and on the potential to sell phosphate rock as direct shipping ore (DSO) in addition to the phosphate grade. Contaminants can include a high level of carbonate and reactive silica, elevated iron and aluminium, fluorine, magnesium, chlorides, cadmium and uranium. The manufacture of most commercial phosphate fertilisers begins with the production of phosphoric acid. Phosphoric acid is produced by either a dry or wet process. In the dry process, rock phosphate is treated in an electric furnace. This treatment

produces a very pure and more expensive phosphoric acid used primarily in the food and chemical industry. The wet process involves treatment of the rock phosphate with acid producing phosphoric acid and gypsum, which is removed as a by-product. Phosphoric acid is the feedstock to production of fertiliser products such as diammonium phosphate (DAP) and monoammonium phosphate (MAP).

THERMAL COAL

Demand

Thermal coal is otherwise known as energy coal or steaming coal. That is, thermal coal is used primarily in the production of heat for the generation of steam and then electricity. According to the World Coal Institute, approximately 39 per cent of the world's electricity is generated through the use of thermal coal. Additional consumption takes place from cement production. Strong demand growth for seaborne thermal coal continued through 2010, driven primarily by growing demand for imported coal by Chinese generators and the ongoing rollout of new generation capacity in India where industrialisation is gaining momentum. Demand in thermal coal markets is expected to remain robust as coal demand continues to be driven by economic growth in Asia and other developing economies, as China continues on its path to industrialisation and India invests in new coal-fired generation to address growing electricity challenges. Analysts report that China and India combined account for 90 per cent of projected near-term demand growth for thermal coal seaborne trade. Other key overseas markets for thermal coal include Japan, Korea and Taiwan.

The demand outlook for thermal coal in European markets is less positive than for India or China, with rising environmentalism and a switch to gas, nuclear and renewable energy power generation mitigating strong long-term thermal coal demand.

Market and pricing

Export sales from Australia are priced either on a spot or index basis, else sales are settled under fixed price term, quarterly or annual supply contracts. Spot sales are more prevalent for thermal coal markets than for coking coal markets. Thermal coal prices rose in 2010 to reach around US\$100/t. The late 2010 floods in Queensland severely restricted coal supply. Seaborne thermal coal prices rose accordingly in Q1 2011 with settlements for first quarter delivery up to the order of US\$130/t to US\$140/t.

Supply

Major organisations that produce thermal coal include Xstrata, Rio Tinto and also BHP Billiton, which has interests in a number of thermal coal mines in Australia (Mount Arthur), Columbia (Cerrejón mine), South Africa (Douglas, Middleburg, Khutala and Klipspruit) and New Mexico, United States (San Juan, Navajo). A joint venture partner with BHP Billiton in the Colombian Cerrejón operation is another global miner, Anglo American: Anglo also operates a suite of thermal coal mines in South Africa both for export sales and local power generation via South African energy utility Eskom. Diversified miners Rio Tinto and Xstrata are also key producers.

Australian thermal coal exports fluctuate to a degree as mines are capable of switching production volumes between thermal and metallurgical coal based upon the relative prices at a given time. Weather disruptions also add volatility to production tonnages.

Geology

Coals are the geological remnants of the past vegetation and forests that covered continents in their geological history. In the process of lithification of the plant remains into rocks, chemical changes result, with hydrogen and oxygen being driven off from the rock composition thereby increasing the overall carbon content in the coal.

Key countries of supply

Australia is the world's largest exporter of thermal coal. Producer countries include: Australia, South Africa, Indonesia, Mongolia, China (domestic supply), India (domestic supply), Columbia and the United States.

Grades

Coals are classified depending upon their carbon content as follows: lignite 45 - 65 per cent carbon; semi-bituminous 60 - 75 per cent carbon, bituminous 75 - 90 per cent carbon, semi-anthracite 90 - 93 per cent carbon and anthracite 93 - 95 per cent carbon. A key aspect of coal seam analysis is to assess CV, measured in Kcal/kg. Results range from 2000 Kcal/kg for lignites and brown coal to over 8000 Kcal/kg for some bituminous coals and anthracite. Higher CV thermal coals attract a price premium.

Mineral processing

Thermal coal is directly sold into export markets and for domestic power generation. Washing of coals can remove excess ash, silica and sulfur waste products.

9.3.2 Base metals

In this section, the key attributes of the aluminium, copper, lead, nickel, tin and zinc mineral markets are briefly outlined.

ALUMINIUM (INCLUDING ALUMINA AND BAUXITE)

Demand

Aluminium demand is led geographically by the major economies of China, North America (the US), Europe and then Japan. China accounted for approaching 17 Mt of aluminium consumption in 2010. By comparison, Western Europe consumed approximately 6.4 Mt and North America 5.8 Mt. The size of global aluminium consumption is estimated at around 43 Mt for 2011. Main end-use demand lies in the transport and construction sectors, combining to account for approximately half of aluminium metal consumption. In transport, aluminium is used as sheet, tube and castings. In construction, aluminium is used in door-frames, windows and building wire. These sectors are augmented by electrical, packaging, foil stock, machinery/equipment and consumer durable end-uses. Aluminium's electrical properties rank below those of copper at around two-thirds of copper's conductivity. Nevertheless, aluminium is a cheaper alternative to copper for some applications and there is demand-side price substitution between the metals depending upon their relative prevailing prices. In 2010 demand continued to recover strongly from the downturn of the GFC, in particular consumption in the transport sector. CRU Group (see the Commodity Research Unit web site) anticipates that demand in the medium term will be driven by continued strong growth in China and in other emerging economies such as India and Brazil. Aluminium is anticipated to pick up additional consumption growth through substitution for copper in wire and heating applications if the copper to aluminium price ratio continues at 2010 levels.

CRU Group estimates that copper substitution by aluminium could add around 200 000 t per year to consumption.

Market and pricing

Aluminium is traded on the LME as a 99.7 per cent grade metal contract as ingot. Intermediate markets such as bauxite and alumina operate on a contract basis, with a component of pricing linked to movement of aluminium prices. Spot prices are more volatile than contract prices along the aluminium value chain. Spot alumina prices have generally exceeded contract prices over the last 20 years. 2010 prices have sat around US\$2000 to US\$2200/t. This contrasts with pre-GFC prices of over US\$2500/t – and a mid GFC low of below US\$1500/t. Historical aluminium prices sat below US\$2000/t until 2006. LME cash and three-month aluminium prices can be viewed at the Base Metals web site. Indicative alumina prices for 2010 sit around US\$325 - 330/t. Indicative bauxite prices for Australia to China trade in 2010 were of the order of \$50/t – price including cost, insurance and freight (CIF).

Supply

Aluminium requires significant energy for its production – hence aluminium smelters tend to be located in regions of the world where low-cost energy supply can be accessed. Recycling provides additional supply to the market. The supply-side of the market is more vertically integrated than for copper, lead and zinc. Vertically integrated alumina refineries supply feedstock to smelters owned by the same entity. Major producers globally include Alcoa, Rio Tinto, BHP Billiton, United Company RusAl in Russia, Hydro of Norway, Chinalco and utility China Power Investment Corporation in China, Hindalco and Vedanta in India. There has been significant excess capacity in aluminium smelting in recent years, with utilisation rates estimated by CRU Group around 80 per cent in 2010. China looks set to dominate new production output in coming years with the majority of the smelter projects in the north and west of China where capital costs for constructing smelters are low and there is access to captive power and coal mines. Regions that are attracting new investment include Inner Mongolia, Ningxia, Qinghai and Xinjiang. India, notably Vedanta, is also planning significant capacity increases to smelting facilities.

Alumina supply growth looks set to be focused in India, Brazil, Australia, Africa and China. Idled capacity exists in the market in 2011 as for alumina refining as for aluminium smelting. Global production for 2010 is estimated by CRU Group at approaching 88 Mt for a utilisation rate of 82 - 83 per cent.

Geology

The ore of aluminium, bauxite, is typically found as a weathering product above granitic rocks with typical economic grades of 30 per cent aluminium. Australia has significant resources of Bauxite, in the Darling Ranges of Western Australia, in Northern Queensland around Weipa and at Gove in the Northern Territory.

Key countries of supply

Aluminium production capacity is greatest in China, approaching 25 Mt – with daylight second. Russia (4.4 Mt), the United States (3.4 Mt), Canada (3.1 Mt) and India (2.7 Mt) stand next in line, followed by the likes of Australia, Brazil, the United Arab Emirates and Norway – all of whom have capacity to produce at least 1 Mt/a of metal. China also leads the world

in alumina production at over 30 Mt followed by Australia at around 20 Mt, then Brazil, the United States and India. Locking in long-term bauxite resources is looming as a challenge for aluminium producers. Bauxite production growth could come from Australia and Vietnam in future years.

Grades

Bauxite is composed primarily of one or more aluminium hydroxide minerals (gibbsite, boehmite, diaspore), plus various mixtures of silica, iron oxide, titanium oxide, aluminosilicate and other impurities in minor or trace amounts. Low silica bauxites, below four per cent SiO_2 , are favoured as low silica reduces the consumption of caustic soda in the alumina refining process. Economic mine grades of bauxite have aluminium content of 25 per cent to over 40 per cent.

Mineral processing

Bauxite is mined by open pit methods – with the ore delivered to nearby alumina refineries for conversion to the intermediate product in the aluminium value chain, alumina. The bauxite ore is digested in caustic soda with the resulting liquor cooled, precipitated and then calcined to form anhydrous alumina.

Alumina production uses the continuous four-stage ‘Bayer Process’ synthesised by Queensland Alumina below (Queensland Alumina is 80 per cent owned by Rio Tinto with Russia’s RusAl owning the remainder):

- Digestion – dissolving bauxite’s alumina content – bauxite is finely ground in mills, then mixed with a recycled caustic soda solution and steam in digester vessels operating at high temperature and pressure. This dissolves the alumina content of the bauxite and the solution is then cooled in a series of flash tanks.
- Clarification – settling out undissolved impurities – the impurities, which remain undissolved, are allowed to settle as a fine mud in thickening tanks. After several washing stages to recover caustic soda, this residue is pumped to storage dams. The solution of alumina in caustic soda is further clarified by filtration.
- Precipitation – forming alumina crystals – the next step involves the recovery of alumina crystals from the caustic solution. In open-top tanks, the solution is stirred by mechanical agitation and seeded with previously precipitated alumina to assist crystal growth.
- Calcination – high-temperature drying of alumina – the precipitated material (called hydrate) is washed and calcined at temperatures exceeding 1000°C . This forms the dry white anhydrous aluminium oxide powder, alumina, which is cooled and conveyed to storage.

Approximately 3.5 t of bauxite are used to make one tonne of alumina. The alumina is then shipped to aluminium smelters where electrolysis with carbon anodes is used to refine the alumina to finished aluminium. Two tonnes of alumina convert to one tonne of aluminium.

COPPER

Demand

The global copper market sits around 18 Mt in total. The metal is mined for a broad range of industrial applications, mostly focused upon copper’s electrical properties. China is the strong growth market geographically – with urbanisation driving copper use in construction applications (building wire) and a shift towards electric and hybrid vehicles

also copper intensive. China currently accounts for over 35 per cent of global refined copper consumption. In the next five years, this proportion is anticipated to increase to over 40 per cent. Copper is under substitution threat from (cheaper) aluminium in some applications and from plastics in other applications. Refined copper is the input to what are known as copper-semis; partly fabricated products that act as a feedstock to end-uses of copper. Copper wire-rod comprises approaching 60 per cent of refined copper consumption. The other types of copper 'semi' are copper/copper alloy tube, copper/copper alloy plate/sheet/strip, copper foil and copper rod and bar.

Market and pricing

Copper is traded on the LME. Copper producers register their individual brands of copper cathode once these are approved as reaching the exchange standards for purity and form. Copper concentrate is traded by contract between owners of mines and of smelters. Concentrate pricing can be wholly via spot contract, under long term contracts, or under contract terms that reflect a proportion of spot and long term contract benchmarks. Smelting companies charge treatment and refining charges to the mine owner as part of the concentrate pricing formula. Additionally, under annual or long-term contracts there is sometime a copper 'price participation' whereby the smelter also receives a proportion of the increase in copper metal price for processing the concentrate when prices exceed a stated benchmark. In recent years, smelters have not been able to win price participation rights in processing copper concentrates as there has been excess smelting capacity available globally. Smelters make their margin from 'free' metal (metal recoveries over and above those agreed as payable to the concentrate seller) and also from sales of sulfuric acid generated by removal of the sulfur from the copper concentrate by the smelter. Most smelters can process both concentrate and copper scrap as smelter feedstock.

Smelting companies prefer to obtain 'clean' copper concentrates from mine owners. Clean concentrates have low levels of impurity elements. Those elements typically classified as impurities by smelter owners are: arsenic (As), antimony (Sb), bismuth (Bi), chlorine (Cl), lead (Pb), mercury (Hg) and zinc (Zn).

The copper price is volatile. In recent years, price volatility has ranged between lows of around US\$3000 per tonne and highs of US\$10 000 per tonne. LME cash and three-month copper prices can be viewed at the Base Metals web site.

Supply

Around 80 per cent of copper is produced from copper sulfide ores via the process of first generating a copper concentrate (typically at the mines site), which is then smelted and refined (usually away from the mine site) to a final product of 99.9 per cent copper. The remaining 20 per cent of copper is produced from electrowinning, which takes place at the mine site, typically when initial ores are oxide in form. Chile's national mining organisation Codelco is the world's largest producer of mined copper. Other major producers include Freeport, BHP Billiton, Xstrata, Grupo Mexico, Anglo American, Rio Tinto, Antofagasta and Teck Cominco. The major companies have a strong organic growth pipeline of major new projects likely to be commissioned over the next decade, in particular Codelco, BHP Billiton, Anglo American and Xstrata. Most new projects remain open pit, with around 30 - 40 per cent of future projects planned as underground developments. Most projects have business costs in the range US\$2000 to US\$3000/t of copper – so margins are very strong for those mines in production for copper prices sit at 2010 levels. New large projects have typical capital intensities of around US\$10 000/t of annual copper production.

Geology

Copper occurs in a variety of geological rock-types. Large open pit mine developments in Chile, the world's largest copper supplier, comprise large copper-gold porphyry systems that are the eroded remnants of large magma chambers. Elsewhere, copper also is produced from sedimentary deposits and from former ocean-floor volcanic massive sulfide deposits. Copper is also produced as a by-product from nickel sulfide deposits, most notably in Canada.

Key countries of supply

Chile, Peru, United States, Zambia, Australia, DRC, China, Indonesia. Mine developments continue to be dominated by South American projects whereas copper smelter capacity growth is focused in China, with CRU Group estimating that up to 80 per cent of new smelter capacity growth will occur in China over the next five years. China currently has around 5 Mt/a copper smelting capacity; CRU Group estimate that this figure could increase by up to a further 3 Mt within five years if all planned smelter expansions and projects proceed. Mine project developers are facing increasing technical and cost challenges as the overall grade of new projects declines relative to current mine grades and remote (infrastructure poor) and deeper copper deposits with more complex metallurgy are accessed. Chile's projects have an advantage in terms of infrastructure – largely being brownfields developments.

Grades

Copper can be mined at run-of-mine grades around 0.5 per cent Cu in large-scale bulk mining open pit scenarios, especially if there is a significant gold credit (eg 0.1 g/t Au or higher). Higher grades tend to be mined in Central Africa, where the deposits grade several per cent copper. Similarly, underground mines developed on volcanic massive sulfide deposits mine several per cent copper, usually in conjunction with zinc and lead in deposits of that style. Average mine grades from future projects are now declining to around 0.6 per cent copper – but this rises to around one per cent copper-equivalent when by-product credits are fully accounted for in revenue terms.

Mineral processing

Sulfide copper ore is first crushed and ground then the resultant slurry is treated in a flotation circuit to produce a copper concentrate grading 30 - 40 per cent copper. The concentrate is presented to a flash furnace and smelted to produce blister copper that is then refined to produce an LME-quality copper end-product. Oxide copper ores undergo hydrometallurgical processing with initial acid leaching of the copper into solution then electrolysis to recover the dissolved copper to cathodes.

LEAD

Demand

Global lead consumption is expected to reach approximately 9.5 Mt for 2011. Lead is used in batteries, in cable sheathing, for pipework and steel and in chemicals and alloys. The main driver of lead's demand outlook is the continued use of lead-acid batteries in automobiles, with hybrid electric vehicles requiring lead-acid batteries during lighting, starting and ignition alongside other emerging battery technologies. China is seen as the major demand growth region geographically, with China already accounting for some 40 per cent of lead consumption globally. After China, the United States is the second largest consumer.

Market and pricing

Lead is traded on the LME as pigs and billets. Miners receive payment for lead from smelters minus treatment and refining charges. Smelters also receive price participation by a formula to gain exposure to upside movements in the LME lead price. Historically, lead prices traded between highs of US\$800/t and lows of US\$400/t during the 1990s and through to the start of the new century. It was not until 2004 that lead prices joined the general move upwards in commodity prices, with the average price approaching US\$900/t that year. Record prices were reached in 2007 when lead averaged over US\$2500/t for the year. Historically, lead traded at a discount to its close associate zinc. In more recent years, lead has competed with zinc on price, sometimes rising above zinc in price for sustained periods. The impact of the GFC saw lead prices fall below US\$2000/t on average for 2009, but prices again rebounded on average in 2010 as the global economy started to recover. Volatility remains the order of the day; lead having sunk as low as US\$1600/t and risen to US\$2600/t for short periods in 2010.

LME cash and three-month lead prices can be viewed at the Base Metals web site.

Supply

Recycling forms a significant component of lead supply due to the relatively short lifecycle of batteries – supplementing primary mine supply. Secondary supply is expected to contribute between 55 and 60 per cent of total lead supply in 2011. As for consumption, China is the main contributor to lead supply and to future lead supply growth. China's production of lead from scrap sources (both domestic and imported scrap metal) is outpacing its primary supply growth from mine output, with Chinese lead smelters increasingly using scrap metal as a source of plant feed.

Geology

The main ores of lead are galena (PbS), anglesite (PbSO_4) and cerusite (PbCO_3). Lead rarely occurs as native metal. In volcanic massive sulfide and Mississippi Valley type deposits containing lead, the mineralisation occurs parallel to the bedding in the rocks, but also occurs in cross-cutting veins and lodes.

Key countries of supply

The main countries in which lead ores are mined are China, Australia, the United States, Peru, Mexico, Canada, Sweden, South Africa, Morocco, Poland and Ireland.

Grades

Economic mine grades for lead vary significantly due to the fact it is commonly mined in association with the likes of copper, zinc and silver. Typical grades vary from as low as two per cent lead up to 20 per cent lead. A useful yardstick in lead/zinc deposits is to look for ten per cent or above combined lead and zinc as an indicator of a quality deposit: Some mines are economic and indeed very profitable below such grades, notably open pits, but the ten per cent rule is a useful starting benchmark. Concentrate grades for lead are typically over 50 per cent lead.

Mineral processing

Production of a lead concentrate occurs at lead mine sites by the technique of froth flotation of ground sulfide ore. Smelting of lead concentrate occurs in a reverberatory or blast furnace.

Smelters levy penalties for deleterious elements such as arsenic and bismuth when present within concentrates.

NICKEL

Demand

Stainless steel is the principal end-product that consumes nickel. Stainless steel is used across many industrial and commercial sectors. The four main uses are in the sectors of: catering and household, industrial, transport and construction.

The most widely used stainless steel type is known as austenitic, which typically contains 18 per cent chrome and eight per cent nickel (cutlery is often marked '18/8'). Austenitic grades account for about 60 per cent of all stainless steel produced. Other uses lie in non-ferrous alloys, electroplating and in batteries.

The main consumers of stainless steel are in the Western Europe, North America and Asia regions. China's consumption growth has outpaced other regions in the last decade.

Market and pricing

Nickel is traded on the LME. LME grade is 99.8 per cent nickel as cathodes with up to 0.1 per cent cobalt content. Tradable physical forms of nickel also include briquettes, granules, pellets and nickel shot. Intermediate markets also exist for ferronickel (typically containing 30 per cent nickel) and for nickel concentrates. Ore is also traded, for example at Kambalda in Western Australia where the concentrator toll-treats ore from surrounding nickel sulfide mines.

Nickel ranks alongside tin in recent years in informal competition to be the highest value contract traded on the LME. Nickel prices in 2010 and 2011 have oscillated in the US\$20 000/t to US\$30 000/t range, well below the ~US\$50 000/t pre-GFC price spike of 2007. LME cash and three-month nickel prices can be viewed at the Base Metals web site.

Supply

BHP Billiton, Vale, Xstrata, Norilsk and China's Jinchuan rank amongst the main global organisations that supply nickel. These names have changed over the last decade as BHP Billiton acquired Australia's WMC, Vale acquired INCO of Canada and Xstrata acquired Falconbridge of Canada.

Geology

Nickel deposits occur as either sulfide deposits or as laterite deposits. In sulfides, the main ore mineral is pentlandite (2FeS , NiS). Sulfide deposits are linked to igneous activity, either within magma chambers that have segregated with the heavy sulfide mineralisation accumulating towards the base of the magma else in ancient lava channels where again the sulfides drop out at the base of the lava flows. Platinum group metals are by-products from nickel sulfide production. In nickel laterites, nickel occurs in combination with cobalt mineralisation (and manganese) in near surface layers where grades have been enhanced through chemical and physical weathering effects.

Key countries of supply

Russia, Canada, New Caledonia, Australia, Indonesia, Cuba, China.

Grades

Laterite deposits typically grade from below one per cent nickel up to three to four per cent. Similarly, sulfide deposits amenable to open pit development can be mined as low as 0.5 per cent nickel but in underground developments can grade up to five per cent nickel and higher.

Mineral processing

Sulfide ores are first concentrated using flotation. Nickel concentrates that result contain between ten and 20 per cent nickel. Concentrate is then smelted to produce nickel matte (typically 75 per cent nickel) and then refined by electrolysis to produce LME grade nickel. Laterite ores contain oxide mineralisation and are therefore not amenable to sulfide flotation. Ore can be smelted to produce ferronickel or can be presented for ammonia or acid leach and then electrowon to produce cathode. At the Minara Resources (MRE)-Glencore nickel laterite operation in Western Australia, the leaching is by high-pressure-acid leach with cobalt as a payable by-product to nickel production.

TIN

Demand

The global refined tin market is anticipated to comprise some 365 000 t metal in 2011. China is the world's largest consumer (and producer). Tin demand is split across several end use sectors, of which solder is the largest use, both for electronic and industrial applications. Indeed, use as solder comprises just over half the total consumption of tin. Tinplate, chemicals and brass/bronze make up the balance of demand along with a plethora of minor uses. Detailed information based on large annual surveys of tin users is available at the ITRI web site.

Market and pricing

Tin is the smallest of the LME non-ferrous metal contracts. The Kuala Lumpur Tin Market also serves as a pricing reference point in some Asian markets. Tin has competed with nickel in recent years for the title of the highest priced of the LME metal contracts. Prices peaking at over US\$27 000/t in 2010 were well above recent historic levels – reflecting a lack of new investment in supply development over the past decade – although all-time highs in inflation-adjusted terms were over \$40 000/t in the early 1980s. LME cash and three-month tin prices can be viewed at the Base Metals web site.

Supply

Yunnan Tin of China is the largest producer of tin globally at around 55 000 t/a. Yunnan Chengfeng and China Tin are also significant Chinese producers at around 15 000 t/a each. Indonesia is host to the world's second largest integrated producer, PT Timah. Malaysia Smelting Corporation ranks third in terms of production, alongside Minsur of Peru, both producing 35 - 40 000 t/a. Thaisarco of Thailand and EM Vinto of Bolivia are also significant producers on a world-scale at around 20 000 t and 10 000 t/a respectively.

Geology

Cassiterite (SnO_2) is the main ore mineral of tin, with ore found either as primary deposits in veins or lodes else in reworked secondary deposits as alluvials. Hard rock deposits are

worked typically as underground mines whereas alluvial deposits are dredged and pumped to recover the ore.

Key countries of supply

China, Indonesia, Malaysia, Bolivia and Peru.

Grades

Alluvial deposits can be economic at lower grades than hard-rock vein-style deposits due to the lower mining and milling costs involved in their extraction. Alluvial grades below 0.5 per cent are common whereas underground hard-rock mines have historically required grades exceeding one per cent tin. However, with the rise in prices in 2008 - 2010, hard rock mines with grades as below 0.4 per cent become potential new entrants to the supply side, especially if there are valuable co-products or by-products. Venture Minerals (VMS) cite the average hard rock tin mine grade of undeveloped deposits as only 0.4 per cent tin.

Mineral processing

Processing is first to tin concentrate by gravity concentration and flotation and then via smelting and refining to final metal of LME grade. Smelting takes place with coal or fuel oil and limestone (as flux) and/or sand may be added to react with impurities in the concentrate.

ZINC

Demand

The global zinc market will comprise over 12 Mt of finished metal in 2011. Principal uses are for galvanising (anti-rust coating), which is by far the greatest end use consumer, in die casting alloys, brass, and as rolled zinc. Galvanised steel is used in the automobile industry to increase the corrosion resistance of vehicles. Galvanised steel is also used extensively in construction and engineering applications and in the manufacture of white goods. China is the largest consumer of zinc, anticipated to reach 5 Mt by 2012, with recent and forecast Chinese consumption growth for zinc far greater than across the western economies. Western Europe is the next largest consumer at around 2 Mt/a. By contrast and for comparison, Australia's zinc consumption sits at around 250 000 t/a.

Market and pricing

Zinc is traded on the LME up to 63 months forward. Zinc concentrates are traded internationally under both off-take agreements and as spot cargoes. Producers of zinc concentrate are paid for the majority of contained zinc in the concentrate, minus a deduction, but pay a treatment charge to the smelter together with an escalator indexed to the prevailing zinc price. Producers of concentrate are also paid for by-products, such as lead and silver, but receive penalties for impurities in the concentrate such as cadmium, arsenic or high iron levels. Typical traded concentrates grades are around 50 per cent zinc per tonne.

Until 1998, zinc traded below US\$1000/t (with the exception being a price-spike of 1974). Since then, zinc has typically traded above that benchmark reaching a peak exceeding US\$3000/t average price in 2006 and 2007. 2010 and 2011 prices have sat around the US\$2000/t mark. LME cash and three-month zinc prices can be viewed at the Base Metals web site.

Supply

Zinc producers can be split between those companies with significant mine output – and other companies with significant zinc smelter capacity. Whilst several companies are fully integrated from mine to metal, the split still serves as a useful delineation. Major miners of zinc globally include (amongst others) India's Hindustan Zinc, Canada's Teck Cominco, international metals trading house Glencore, diversified miners Xstrata, Anglo American, BHP Billiton and Sweden's Boliden. Major smelting companies include (again amongst others) Nystar, Korea Zinc Group, Hindustan Zinc, Votorantim, Boliden, Penoles, Mitsui and Toho Zinc.

Geology

There are a number of commercial zinc ores, with the most important being sphalerite (ZnS_2) and smithsonite (ZnCO_3). Zinc commonly occurs with other metals, with lead-zinc-silver the main association in Mississippi Valley Type deposits (MVTs) and copper-zinc-gold-silver in volcanic massive sulfide (VMS) deposits.

Key countries of supply

China, Canada, Australia, Peru, the United States, Mexico, Kazakhstan, Ireland and Bolivia.

Grades

In zinc/lead deposits, grades of combined metal that exceed ten per cent are considered attractive. Mine grades of zinc at high-grade mines can exceed 20 per cent.

Mineral processing

Zinc sulfide ore is first ground then subjected to froth flotation. At the smelter, zinc metal is formed from roasting to produce sinter, removing the sulfur, which is converted to sulfuric acid. Sinter is mixed with coke and heated to separate zinc from lead when a mixed concentrate is the source. Final metal is refined via distillation. Distillation involves the use of fractionating columns comprising rectangular trays of silicon carbide refractory material and arranged to allow a descending flow of liquid metal and an ascending flow of metal vapour. The zinc is vaporised and freed from impurities with higher boiling points, such as lead and iron. The distilled vapour is condensed and fed into a second column, where the remaining impurity, cadmium, with a boiling point lower than that of zinc, is distilled. High-purity zinc is then run off from the bottom of the column.

9.3.3 Diamonds and precious metals

In this section, the key attributes of the diamonds, gold, platinum group metals and silver mineral markets are briefly outlined.

DIAMONDS

Demand

Retail and industrial sales are the key sources of diamond demand. End-use demand is a function of diamond quality. Gem quality diamonds are the most sought-after; however, 'near gem' (meaning rough uncut diamonds) and industrial quality diamonds are also co-products of diamond mines. The sales and marketing of gem quality diamonds drives industry revenue, with a focus emerging to target the growing Chinese middle class

demographic as a key growth market. China is now the second largest market for diamonds, behind the United States – and along with India, is a key driver of market growth. Global rough diamond sales in 2010 sit above US\$4 billion.

Market and pricing

In the world of diamonds, quality is the key determinant of sale price – and hence one key source of margin – for producers. High quality diamonds sell for many times more than those of average quality. For example, it is estimated that the top two per cent of diamonds by quality account for about 15 per cent of the market by value. Price is set by assessment of the four 'C's of diamond quality.

From a market perspective, diamond supply is closely linked to the activities of the Central Selling Organisation (CSO). About 80 per cent of the world's rough diamonds are sold by the CSO. The CSO has historically been able to manage supply inventories so that periods of over-supply in the market do not result in price collapse, much to the annoyance of buyers who have taken the perspective that such inventory management is conducted purely for the reason of maintaining artificially elevated price levels.

Diamonds are graded into over 5000 categories on the basis of weight, colour, clarity and proportion by skilled diamond sorters.

The 'four C's' represent the four main variables that are used to calculate the quality and value of a diamond. Both rough and cut diamonds are separated and graded based on these four characteristics. The four variables are cut, carat, clarity and colour. The cut of a diamond is not simply its shape. The way a diamond is cut is primarily dependent upon the original shape of the rough stone, location of the inclusions and flaws to be eliminated. Cut is seen as perhaps the key criterion. A diamond or gemstone's 'carat' designation is a measurement of both the size and weight of the stone. One 'carat' is a unit of mass that is equal to 0.2 g (200 milligrams or 3.086 grains) or 0.007 oz. A carat can also be divided into 'points' with one carat being equal to 100 points, and with each point being 2 mg in weight. Therefore, a 1/2 carat diamond would be 50 points, a 3/4 carat diamond is 75 points and a two carat diamond is 200 points.

Clarity is assessed on a grading scale as below, with flawless (FL) the highest clarity rating:

- FL – 'flawless' no inclusions at 10× magnification
- IF – 'internally flawless' no inclusions at 10× magnification – small blemishes
- VVS-1 – 'very, very small' inclusions hard to see at 10× magnification
- VVS-2 – 'very, very small' inclusions, VVS1 better than VVS2
- VS-1 – 'very small' inclusions visible at 10× magnification – not naked eye
- VS-2 – 'very small' inclusions VS1 is better grade than VS2
- SI-1 – 'small' or 'slight' inclusions or 'imperfections' may be 'eye clean'
- SI-2 – 'small' or 'slight' inclusions or 'imperfections' visible to naked eye
- SI-3 – inclusions large and obvious, little or no brilliance
- I1 to I3 – imperfect, with large Inclusions, fractures and flaws.

Finally, colour rating is assessed. All natural diamonds contain small quantities of nitrogen atoms that displacing the carbon atoms within the crystal's lattice structure and structural defects from a perfectly formed lattice: Both these effects cause a colouration of the diamond gemstone. Nitrogen impurities absorb some of the blue light spectrum, thereby making the diamond appear yellow. The higher the amount of nitrogen atoms the yellower is the stone.

In determining the colour rating of a diamond, gemmologists' use a scale of 'D' to 'Z' in which 'D' is totally colourless and 'Z' is yellow:

- D, E, F – colourless (white)
- G, H, I, J – near colourless
- K, L, M – faint yellow or brown
- N, O, P, Q, R – very light yellow or brown
- S, T, U, V, W, X, Y, Z – light yellow or brown.

The best quality stones are sold by diamond tender process. For Rio Tinto's Argyle mine for example, each year, a small collection of the best pink diamonds are offered in an exclusive sale known as the Argyle Pink Diamond Tender. It is estimated that for every 1 000 000 carats (200 kg) of rough pink diamonds produced by the mine, only of the order of one carat (0.20 g) polished will be of sufficient quality to be lodged for sale at the tender.

Market leader De Beer's is known for its process of selling diamonds by 'sight'. Sights take place ten times a year in London, although simultaneous smaller sights are held in Switzerland and South Africa. Clients, known as sight-holders, submit their requests for a mix of diamonds about a month before each sight takes place. The buyer, however, does not know to what extent the request has been fulfilled until the day of the sight.

Supply

Global mine production sits around 170 million carats per annum. De Beers (the world's largest producer) produced some 48 million carats in 2009. Diversified miners Rio Tinto (approaching 21 million carats in 2009) and BHP Billiton (3.5 million carats in 2009) are important diamond producers. Russian-based producer Alrosa (34 million carats in 2009) is the world's second largest producer behind De Beers. In Russia, Alrosa carries out diamond mining operations at nine primary and ten alluvial diamond deposits. Alrosa is also mining diamonds in Angola. Rio Tinto operates the Argyle diamond mine in Western Australia's Kimberley region whilst BHP Billiton currently (March 2011) operates the EKATI mine in Canada¹.

Geology

Diamonds occur in their native state. Primary diamond deposits occur within a variety of volcanic pipes of specific geological origin and composition. The pipes have a kimberlite or lamproite chemistry to them, being ultrabasic in mineralogical composition. Erosion of these pipes releases diamonds for concentration into secondary deposits, where the diamonds are washed into alluvial deposits within sediments. Dredging of alluvial sediments in which eroded diamonds may have concentrated provides an opportunity to source diamonds within recourse to hard-rock mining.

Key countries of supply

Australia is the largest global producer of diamonds by volume, from the Argyle mine in the Kimberley region of Western Australia. However, as the majority of Australian diamonds are of relatively low value, Australia does not lead the world on a value-basis. Botswana lays claim to being the most significant global producer by value. Other significant producing countries include Canada, the Democratic Republic of Congo, Russia, South Africa, Angola, Brazil and Namibia. Main global centres for the processing

1. The Ekati project was up for sale at the time of writing.

(and trading) of rough diamonds include Belgium (Antwerp), India (notably Surat), Israel (Tel Aviv) and the United States (New York).

Grades

Mine grades of diamonds are expressed in carats per hundred tonnes. There are now hard and fast parameters as to what constitutes high and low grade; however, for guidance, a grade of less than 0.1 carats per tonne is 'low' (ie ten carats per hundred tonnes) and grades exceeding five carats per tonne 'high' (500 carats per hundred tonnes).

The value per carat varies significantly from mine to mine. Argyle has a very low value per carat (compensated by high grade) whereas Diavik and Ekati yield diamonds with typical average value of US\$100 per carat. The Merlin diamond pipes owned by North Australian Diamonds (NAD) yield diamonds with average value US\$200 per carat whilst some African mines yield higher values up to and beyond US\$400 per carat such as the Letseng mine in Lesotho and the Victor diamond mine in Ontario, Canada.

Mineral processing

A diamond processing plant typically uses crushing, screening then heavy-medium separation (HMS) followed by X-ray fluorescence sorting diamond recovery. At the Argyle mine in Western Australia, 3 mm ore forms the feed for the heavy-medium separation circuit while -1 mm material is rejected to the plant tailings. Heavy medium cyclones are the key to the separation process, with material denser than the cut point forming the diamond-bearing concentrate. X-ray sorting separates the diamonds from residual waste in the HMS concentrate, the recovered stones being acid washed before sorting for shipment.

GOLD

Demand

Gold demand is split between its fabrications uses and its role in finance, where it has a dual role as a store of value and as an investment. Fabrication demand encompasses gold's use in jewellery, electronics, dental, coins and medallions and also in various industrial applications. Total fabrication demand in 2010 approached 2700 t of gold, down from around 3000 t in 2007 due to fabrication consumers paring back purchases as the gold price increased.

Investment demand includes gold-backed securities. Gold ETFs have risen in popularity in recent years, in part as the transaction costs of holding of gold-backed ETFs are lower, certainly for small holders, than the direct costs associated with the actual purchase, storage and insurance of physical gold bars. ETFs also provide immediate liquidity of gold investments for their holders. The largest gold trust, SPDR, reported total gold holdings of 1290.86 t (41 502 Moz) in early December 2010, with units traded on exchanges in New York, Singapore, Hong Kong and Tokyo (SPDR Gold Shares GLD, n/d).

Market and pricing

Gold is bought and sold on exchange traded markets across the world including London, New York, Tokyo, Hong Kong and Dubai (Spall 2009). Gold prices are typically denominated in US dollars, although price quotes in multiple currencies are continuously available via precious metals web site Kitco.com. The Australian dollar gold price is of particular importance to domestic producers. The last decade has seen a gradual increase in gold price

to over US\$1400/oz at end 2010 and more recently above US\$1700/oz. This price seems a long way from the 1990s typical prices of US\$300 - 400/oz. The late 1990s and years 2000 and 2001 were particularly weak years for the gold price with average prices below US\$300/oz. Gold prices then rose in price each year since 2002.

Supply

Gold mine supply in 2010 is of the order of 2600 t. Scrap supplies are also significant contributors to the gold market – as anyone who has seen television advertisements offering to buy old jewellery will attest. Scrap supply rises as prices rise, with 2010 gold scrap totalling in the order of 1600 t. Some 30 000 t of gold is held globally by the reserve banks of different countries. Treasurers make decisions to either acquire additional gold for currency reserve purposes else to sell down their gold holdings. Predicting these decisions is of course difficult. In recent years the trend has been for the reserve banks of developing countries to be net buyers of gold whereas some developed countries have chosen to sell down their gold reserves. In reserve holdings, the largest central bank gold stocks are held by the United States at over 8000 t, followed by the banks of Germany (~3400 t), France and Italy (~2400 t each) then Switzerland and China (each holding ~1 t). Australia's reserve gold holdings in 2012 stand at 79.9 t.

Geology

Gold typically occurs in its native state within rocks. There is an old saying prevalent in the mining industry that 'gold is where you find it'. This statement fits with the fact that gold can occur within a wide range of rock-types – and in rocks of all different ages. Different types of gold deposit include vein-style deposits, such as those that dominated hard-rock historical production in the Ballarat-Bendigo region through to alluvial deposits of gold (also present at Ballarat-Bendigo) where the gold has been first eroded and then re-deposited by ancient river channels. Gold also occurs with other minerals in some deposits, most notably in gold-silver deposits and gold-copper deposits.

Key countries of supply

China is now the world's largest gold producing nation (~350 t/a), followed by Australia (~240 t/a) and South Africa and the United States (both ~210 t/a in 2010). Other significant producing nations include Peru, Ghana, Papua New Guinea, Brazil and Argentina – but the list of producing nations is a very long one – including for example, New Zealand, where Oceanagold Corporation (OGC) have significant operations as does United States-based company Newmont.

Grades

The average grade of Australian gold production is now below 2 g/t gold. In the past such a grade would have been considered low, but the higher gold price (therefore higher value per tonne of ore) and the dearth of new higher grade mining opportunities has driven average grades lower. Open pit grades are typically 1 g/t and above, with open pits exceeding 3 g/t now considered high grade. Underground mines typically produce gold at grades of 4 g/t and above.

Mineral processing

Gold can be physically separated from crushed rock through gravity sorting given its very high density – although gravity separation typically does not release all the gold from

the rock. Non-refractory gold (after gravity sorting) is typically treated using cyanide as a leaching agent, either in leach tanks or alternatively using heap leach pads. Carbon is then added in the carbon-in-pulp (CIP) process to release the gold from the cyanide solution. The loaded carbon is then stripped of gold using electrolysis. Refractory gold is processed initially in using flotation to produce a sulfide rich gold concentrate and then roasted to convert the sulfides to oxides, thus allowing cyanide leaching to recover the gold. Gold dore produced at mine sites (usually 70 - 90 per cent gold) is then typically transported to an off-site specialist refinery for final processing.

PLATINUM GROUP METALS

Demand

Platinum group metals (PGMs), alternatively platinum group elements (PGEs), is a collective term used to describe the following elements; platinum (Pt), palladium (Pd), rhodium (Rh), iridium (Ir), ruthenium (Ru) and osmium (Os). The first three metals comprise the main PGMs.

Industry specialists Johnson Matthey publish a free half-yearly market overview for platinum group metals, available for download from their web site.

Platinum gross demand is estimated by Johnson Matthey at 7.56 Moz for 2010, a rise of 11 per cent from 2009 driven by increased autocatalyst and industrial demand. To derive the net new demand growth, Johnson Matthey estimate that recycling of platinum from the autocatalyst and jewellery sectors will also have risen in 2010, but not sufficiently to offset the observed growth in gross demand – with net demand for platinum therefore rising approximately six per cent to 5.72 Moz in 2010.

Johnson Matthey report demand for platinum jewellery fell in 2010 due to higher platinum metal prices, down approximately 14 per cent to 2.4 million ounces. The increased price has also driven up recycling levels in the sector, resulting in net jewellery demand reducing by approaching 25 per cent to 1.69 Moz. Industrial demand for platinum is expected to increase to 1.72 Moz – with platinum consumed in electrical and consumer goods, in the chemical industry, and in the manufacture of LCD glass. ETF demand is also a factor as platinum's investment appeal as a precious metal has risen in recent years. 2010 estimates indicate around one million ounces of platinum is consumed as ETF asset backing. Europe leads the autocatalyst demand for platinum whereas China leads jewellery demand for platinum. North America leads investment demand.

Rhodium gross demand is estimated for 2010 at around 875 000 oz with higher autocatalyst, chemical and glass demand responsible for consumption growth. The building of new LCD manufacturing lines in China, Japan and South Korea is expected to further raise rhodium demand.

Palladium demand is driven by autocatalysts and industrial uses in addition to ETF purchases. China and Europe are the leaders in palladium consumption for autocatalysts with China leading jewellery demand. North America leads investment demand. Johnson Matthey estimate 2010 gross demand at 8.9 Moz with demand net of recycling at 7.1 Moz (recycling at 1.8 Moz). Automotive demand is the principal end-use at around 5.0 Moz gross consumption. Demand for palladium for electrical uses is around 1.4 Moz (gross). Gross jewellery and investment demand both sit around 630 000 and 670 000 oz respectively with minor uses including dental applications making up the remainder.

Ruthenium demand in 2010 is expected to exceed one million ounces for the first time: demand growth being from the electrical sector, particularly the use of ruthenium in hard disk drives.

Iridium demand is benefiting from the growing focus upon highly efficient lighting systems using LED technology, with iridium crucibles used in single-crystal growing for LED manufacture. Demand for iridium also comes from the automotive sector for use in spark plugs.

Market and pricing

Product is sold as ingots and a range of smaller sized bars. Refiners and producers operate brand codes for platinum and palladium products. Futures contracts are available and traded including on the Tokyo Commodity Exchange (TOCOM) and New York Mercantile Exchange (NYMEX). Platinum ETFs are growing in popularity. An example is the ZKB (Zurcher Kantonalbank) Platinum ETF that is listed on the SIX Swiss Exchange and which commenced trading in 2007. Platinum, palladium and rhodium prices are continuously available via precious metals site Kitco.com. Platinum group metals refiner Johnson Matthey maintain a flexible web-based chart facility for historical prices of platinum, palladium, rhodium, iridium and ruthenium (Johnson Matthey, n/d).

Platinum prices exceeded US\$2000/oz prior to the GFC, but then fell below US\$1000/oz in late 2008. A gradual recovery as automotive demand and investment demand has increased saw prices rise above US\$1500/oz once again in 2010. Palladium prices rose above US\$500/oz prior to the GFC, but the downturn in demand saw prices fall back to only around US\$200/oz by late 2008. Since end 2008, however, palladium has recovered strongly, buoyed in 2010 by supply fears. Specifically, there are doubts that Russia has much palladium left in stockpiles and the world's biggest producer, South Africa, continues to struggle with power shortages and labour unrest. End 2010 prices had returned to pre-GFC levels at US\$500/oz on a strong uptrend. Rhodium prices in 2010 were above US\$2000/oz trending upwards; however, well below the early 2008 price peak of US\$10 000/oz. Iridium prices have risen above US\$750/oz in 2010, exceeding pre-GFC levels of US\$450/oz and below. Ruthenium traded at around US\$180/oz in late 2010, below its brief 2007 peak above US\$800/oz.

Supply

Major platinum producers globally include Anglo Platinum, Impala Platinum and Lonmin, all operating in South Africa – and Norilsk Nickel of Russia. These organisations also produce palladium. North American production comes from the Stillwater mine in Montana, owned by the Stillwater mining Company, and from Xstrata's Canadian (Sudbury) nickel operations. Australian-listed producers include Zimplats Holdings (ZIM) from their Zimbabwe operations. Anglo Platinum also operates in Zimbabwe. Recycling of PGMs augments mine production: Recycling takes place from autocatalysts, electronics and jewellery end uses.

Geology

Primary deposits of PGMs occur within layered basic igneous intrusions, with the Bushveld Igneous Complex of South Africa the typical example. Elsewhere, PGMs occur as by-products within nickel-bearing sulfide deposits, such as those in Canada's Sudbury Region and to a lesser extent Western Australia's Kambalda Region.

Key countries of supply

South Africa is by far the largest supplier of platinum. Russia is the next largest contributor to mine supply with by-product supply from Canada's nickel mines at Sudbury also making a contribution. In palladium, the relative positions of Russia and South Africa are reversed, with Russia leading production.

Grades

The platinum price is generally of the same order of magnitude as the gold price – thus high-grade and low-grade in platinum deposits, to a first approximation, can be compared to high and low grades for gold deposits. The difference lies in the fact that platinum mines are typically underground, whereas gold mines are split between underground and open pit developments. The comparison of underground grades is therefore the more appropriate. Grades over five grams per tonne combined platinum group metals are attractive, more so if the weighting of the 'basket' of metals in a resource includes significant platinum and rhodium.

Mineral processing

Platinum ore is first crushed and ground prior to froth flotation to produce a concentrate that is dried and smelted. Smelting in a submerged arc furnace at over 1500°C produces a matte product. The matte is periodically tapped and treated in air converters to liberate iron and sulfur allowing a cleansed matte to be subjected to electrolytic refining, distillation and ion exchange. By-product copper, nickel and cobalt are recovered in the electrolytic process.

SILVER

Demand

Fabrication uses for silver include jewellery and silverware, coins and medals, photography and electrical/electronic applications. Further applications exist in solders, alloys and catalysts. Global silver consumption peaked at over 27 000 t in 2000, with 2011 consumption anticipated to sit around 25 000 t. Additionally, as a precious metal, silver is also subject to significant investment demand, with various funds, including ETFs holding significant physical metal stocks, estimated up to 15 000 t. Of this tonnage, the world's largest silver backed ETF, iShares Silver Trust advised that its holdings sat above 10 900 t in December 2010. Electrical and electronic uses continue to grow strongly whilst silver demand for photographic use has been in absolute decline for over a decade now. India is a major consumer – as is Europe, China, the US and Japan.

Market and pricing

Silver is quoted and traded on exchanges such as COMEX and LME, with price quotes varying throughout the day. Silver prices have risen significantly over the last decade – in line with the rise in the gold price. Silver was trading at just US\$4/oz in 2001, rising steadily to reach over US\$20/oz in 2008 and again in 2010. Late 2010 silver prices breached US\$30/oz. Silver prices are continuously available via precious metals site Kitco.com.

Supply

Silver supply originates both from primary mine output and secondary scrap supply. Mine supply is often as a co-product or by-product with other metals. Scrap supply originates from silver's end uses in photography, electronics and catalysts.

Geology

Native silver is normally found in combination with other metals. The principal silver ore is argentite (Ag_2S). Silver occurs in close association with lead-zinc mineralisation and is produced as a by-product at lead-zinc mines. Silver is also a common by-product for several styles of gold deposit and at some copper mines.

Key countries of supply

The largest producing countries are Mexico (~4000 t annual production), Peru (~3500 t), China (~3000 t), Australia (~2000 t) and Russia (~1500 t). Poland, Chile, Bolivia are also significant producers at around 1300 t each per annum along with the US (1100 - 1200 t). Africa is a modest producer totalling only some 500 t/a.

In Australia, silver is produced in Queensland at Mt Isa (by London-listed Xstrata) and at Cannington (by BHP Billiton), in New South Wales at Broken Hill (Perilya Limited, PEM) and as a by-product at South Australia's Olympic Dam (BHP Billiton) along with a number of smaller mines where silver is a smelter credit and hence by-product of VMS copper-zinc deposits. These include production from the Chinese-owned MinMetals' Golden Grove mine and Independence Group's (IGO) Jaguar mine, both in Western Australia. OZ Minerals (OZL) Prominent Hill copper-gold mine also produces silver as a by-product. A small silver credit also often occurs at 'pure' gold mines, such as those of the Kalgoorlie region. The silver concentrates in the dore but is often of a quantum that only part-covers gold refining costs.

Grades

Silver grades can run into hundreds of grams per tonne. At Mount Isa the run-of-mine grades are 150 g/t Ag whereas at Broken Hill, the typical grade is around 50 g/t Ag.

Mineral processing

Silver is concentrated within base metal concentrates then removed during refining. Silver grades typically increase ten-fold from ore to concentrate, such that a base metal concentrate for smelter delivery can run in excess of 1000 g/t Ag. Silver in gold ores is concentrated with gold in the cyanide process and recovered along with gold in the dore at the mine. The silver is then separated from the dore during refining.

9.3.4 Speciality metals and industrial minerals

In this section, the key attributes of the antimony, chromium, cobalt, lithium, mineral sands, molybdenum, niobium, potash, rare earths, tantalum, tungsten, uranium and vanadium mineral markets are briefly outlined.

ANTIMONY

Demand

Antimony's main use (as antimony trioxide) is to act as a flame retardant in children's clothing, toys and plastics for aircraft and car seat covers. Flame retardant uses comprise over half antimony's end uses. Antimony is also used as an alloy with lead in lead-acid car batteries to extend battery life, in corrosion-resistant pumps, anti-friction bearings and also in selected ammunition alloys. Other uses of antimony include pharmaceuticals,

microelectronics, fireworks, pesticides, in specialist glasses and fluorescent light bulbs. An emerging use for antimony is in new generation memory devices for computers, handheld organisers and mobiles. The global market in 2010 is estimated at 180 000 t.

Market and pricing

Mine producers are either integrated through to antimony smelting else sell their mine product to smelters. Sale of mine concentrate, antimony compounds and metal are by contract; there is no exchange trade of antimony. There is also a significant secondary market in recycled antimonial lead (30 - 40 per cent). Final China metal product is classified by grade, I (>99.85 per cent), II (>99.65 per cent), III (>99.5 per cent) and IV (>99.0 per cent).

Antimony metal prices were indicatively US\$11 000/t in 2010, having risen from around US\$1000/t in 2001. In this respect, antimony prices could be considered analogous to copper prices in terms of their order of magnitude (and price trend of the last decade). Indicative prices for antimony products including both trioxide and ingot can be viewed at the Metal Pages web site.

Supply

Statistics on Chinese production vary considerably with output from individual mines not available. The provinces of Guangxi, Hunan, Yunnan and Guizhou are producers of antimony. In Australia, antimony concentrates are produced from the Costerfield gold-antimony mine in Victoria and sold to Chinese smelters by Toronto-listed Mandalay Resources (TSX: MND). The largest refinery is at Hsikwangshan Mining Administration in China, with capacity over 30 000 t/a, producing metal, trioxide, pentoxide and sodium antimonite.

Geology

Antimony most commonly occurs as the mineral stibnite, an antimony sulfide Sb_2S_3 – but also as antimony oxide minerals, cervantite and valentinite, and in over fifty minor minerals. Stibnite is silvery-grey metallic in appearance and often occurs with a bladed crystalline habit. Stibnite is found in veins with other minerals having been deposited by hydrothermal fluids passing through the rock. The most common other mineral and metal associations are with lead, silver, copper, arsenic and gold.

Key countries of supply

China is the main producer of antimony responsible for over 80 per cent of global production. South Africa, Bolivia, Russia, Tajikistan and Kyrgyzstan also contribute significant volumes to the market.

Grades

Ore grades vary from several tens of per cent antimony in individual rock specimens to fractions of a per cent in association with other metals. Bulk grades above two per cent antimony are considered to have potential for underground mine development. Final metal is sold as pure antimony with trace concentrations of arsenic, lead, copper, iron, sodium, tin and sulfur.

Mineral processing

Antimony ores are first crushed, gravity concentrated and processed into concentrates by froth flotation prior to roasting. Concentrate grades are typically 60 per cent Sb and generally

range from 55 - 63 per cent Sb. Deleterious elements that need to be minimised within the concentrate in order to allow sale to smelters include arsenic, copper, lead, bismuth, mercury, selenium and tellurium. Antimony concentrates are subsequently refined into metal or saleable compounds such as antimony trioxide. Antimony metal is marketed with a purity of 99.65 - 99.99 per cent Sb.

CHROMIUM

Demand

Ferrochrome and chromium metal are principally used in stainless and heat-resisting steels (over 90 per cent) with the balance in refractories and chemical pigments. Chromium's biggest benefits in metallurgical usage are its corrosion resistance, hardness, strength and bright finish.

China is the world's leading consumer for high-carbon ferrochrome alloy (FeCr, also containing six to eight per cent carbon), followed by Europe, Japan and the United States. Demand for chromite and ferrochrome is expected to remain strong mainly due to the continued growth of China's stainless steel industry. In 2010, global demand for high-carbon ferrochrome was over 8 Mt and is anticipated by CRU Group to exceed 10 Mt by 2014.

Market and pricing

There are a number of traded products, notably metallurgical, chemical, foundry and refractory grades of chromite. Ferrochrome and pure metal are both traded. Carbon content is a key parameter in terms of saleable product specification. Ferrochromium categories include high-carbon ferrochromium (6.0 - 8.0 per cent C), a category including medium-carbon (0.8 - 1.5 per cent C), low-carbon (0.1 - 0.5 per cent C), and carbon-free (0.01 - 0.06 per cent C) ferrochromium. There are no economic substitutes for chromite ore in the production of ferrochrome, chromium chemicals, or chromite refractories at present.

Indicative metal prices can be viewed at the Metals Pages web site.

Supply

South African focused organisations are the principal suppliers of chromite and ferrochrome. These include Samancor and Chromex of South Africa, Xstrata and Assmang. Samancor Chrome's mines are located on the eastern limb (Eastern Chrome Mines) and western limb (Western Chrome Mines) of the Bushveld Igneous Complex. Typical production levels amount to some three million per annum of saleable chromite ores for both internal consumption as smelter feed (approximately 2.3 million metric tonnes per annum) and local and export sales (approximately 0.7 Mt/a). Samancor Chrome also operates three smelting operations being, Ferrometals, Middelburg Ferrochrome and Tubatse Ferrochrome. Chromex operates the Stellite mine and Mecklenburg chromite project. Diversified miner Xstrata owns a ferroalloy business unit that operates chrome mining operations within the Bushveld Igneous Complex of South Africa. Assmang's Chrome Division consists of the Dwaarsrivier chrome mine and the Machadodorp ferrochrome works both in Mpumalanga. Other chromite and ferrochrome producers include London-listed International Ferro Metals Group.

Geology

Chromium is not found in nature in native metal state. The ore mineral of chromium is chromite (FeOCr_2O_3). Chromite is a brownish-black mineral of high specific gravity that

occurs within layered mafic and ultramafic igneous intrusions. Whilst many rocks contain chromite in small amounts up to one to two per cent, notably in peridotites and in mafic volcanic rocks, economic concentrations are rare.

Key countries of supply

The following countries are chromite producers: South Africa, Kazakhstan, India, Turkey, Finland, Sweden, Zimbabwe, Brazil, Albania, Madagascar, Oman, Philippines, Iran, China and Russia. South Africa is the world's largest producer of ferrochrome. The country holds about 70 per cent of the world's total chrome reserves, mostly located in the Bushveld Igneous Complex ores within what are known as the LG (Lower Group) and UG (Upper Group) chromite seams. South African platinum mines also produce chromite as a by-product.

Grades

Typical 'run of mine' grades of chromite ore contain 28 - 45 per cent Cr_2O_3 , equivalent to 50 - 90 per cent chromite that occur within layers or zones 0.3 - 3.0 m wide.

Mineral processing

Initial processing of chromite ores involves physical sorting or beneficiation of lumpy ores (direct shipping ores), and heavy media or gravity separation of finer ores, to remove gangue or waste materials and produce upgraded ores or concentrates. Magnetic separation and froth flotation techniques have also been applied in some cases. The conversion of chromite to ferrochromium alloys is dominated by electric submerged arc furnace smelting with carbonaceous reductants (or silicon or aluminium), predominantly coke, and fluxes to form the correct slag composition. Other metallurgical processes include electrolysis and thermal dissociation. For the production of pure chromium the iron is separated in a two-step roasting and leaching process. Chromium metal is also produced on a commercial scale by electrolysis of an ammonium chromium alum solution prepared either from chromium ore or from high carbon ferrochromium.

COBALT

Demand

Cobalt is used in chemicals (rechargeable batteries, ceramics, dyes, catalysts), superalloys (aerospace engines, prosthetics, land based gas turbines, other engineering applications), cemented carbides and magnets. The main use is chemicals at around 50 per cent of total consumption. Demand for cobalt in batteries look set to underpin future growth – including anticipated strong growth in demand for electric and hybrid vehicles. The global market for cobalt now exceeds 60 000 t of contained cobalt metal, up from half that amount in the mid-1990s. China and regional Asia are the main consumers for chemicals consumption of cobalt, with Western Europe the leading geographic region for superalloy demand (largely driven by aerospace applications). Chemical uses of cobalt are as follows:

- cobalt oxide used in lithium ion rechargeable cells and in ceramic colouring
- cobalt acetate used for manufacturing polyethylene terephthalate (PET) used in packaging applications
- cobalt nitrate and cobalt carbonate used in oil refineries to de-sulfurise petroleum products
- cobalt chloride used in tyres and gas-to-liquids (GTL) catalysts

- cobalt hydroxide used in downstream cobalt chemicals manufacture and in nickel cadmium and nickel metal hydride batteries
- cobalt sulfate used in electroplating and as an animal feed additive
- cobalt carboxylates used in paint and ink driers and adhesives in tyre manufacture.

Cobalt superalloy consumption leverages the metal's resistance to high temperature and to chemical attack and abrasion. Main cobalt superalloy consumption lies in jet engines; however, other applications for cobalt superalloys have also grown including:

- prosthetics, where cobalt superalloys, along with molybdenum and chromium leverage their strength and corrosion resistance in the manufacture of hip and knee replacement joints
- power generation, in land-based power turbines, which can experience similar operating environments to jet engines
- other industrial superalloy applications such as high temperature furnaces, nuclear power plants and use in high pressure/temperature oil and gas drilling, in special steels and hard-facing products against wear resistance.

In cemented carbides, cobalt is used again for its wear and tear resistance in a variety of machine tools including in diamond cutting tools and mining equipment. In magnets, cobalt is used along with rare earths in the cobalt-samarium magnet used in electronics and robotics.

Cobalt oxide and hydroxide are used in battery applications notably for rechargeable handheld devices (with all battery types requiring a cobalt component as part of the electrodes) and also in electric and hybrid vehicles. Battery applications are the fastest growing cobalt consumption end-use segment.

Market and pricing

Historically, cobalt has been traded entirely by contracts of agreement between buyers and sellers in a somewhat opaque market where prices were difficult to determine. More recently, producers of cobalt have been willing to advise sale prices through web-based information portals – and in 2010 cobalt commenced trading on the LME. The specifications of the LME contract are for metal to be at least 99.3 per cent purity in order to reach LME specification. Typically cobalt has been traded as either 99.3 per cent or 99.8 per cent purity.

Cobalt has a history of significant price volatility. Price volatility has been in part due to the relatively small global market and also the fact that around half the total mine production of cobalt is produced as a by-product. As such, cobalt production tends to not immediately respond to either scarcity or over-supply in the market. Prices lows are typically around US\$4 - 6/lb whereas high prices can reach over US\$30/lb and has briefly traded above US\$50 per pound. Indicative prices for cobalt products, including 99.3 per cent and 99.8 per cent metal, can be viewed at the Metal Pages web site. LME cash and three-month cobalt prices can be viewed at the Base Metals web site. China's largest cobalt producer Jinchuan Group post prices for their electrolytic grade cobalt at their web site.

Supply

Supply from copper-cobalt and laterite-style nickel operations are the main sources of cobalt. Global supply is in the order of 60 000 t cobalt. Global mining and metals companies such as Brazil's Vale, Russia's Norilsk, China's Jinchuan Group, Zambia's Chambishi Metals and Japan's Sumitomo produce cobalt. Freeport-McMoran's Tenke Fungurume copper-cobalt project in the Democratic Republic of Congo (DRC) is becoming a major source of

production with potential to reach 8000 t/a. Higher grades of cobalt at the Tenke project in the initial years are expected to result in higher than life-of-mine average annual cobalt production volumes.

Geology

In tropically weathered regions, cobalt can be concentrated with nickel, iron and manganese bearing minerals in the near surface weathering profile, in particular above ultramafic rocks. In the Copper Belt of Central Africa, cobalt mineralisation is closely related to copper mineralisation.

Key countries of supply

Democratic Republic of Congo (DRC), Zambia, Australia, Cuba, Morocco, New Caledonia, Russia, Canada, Brazil, China.

Grades

Low-grade cobalt ore of around 0.05 per cent cobalt is mined in conjunction with nickel laterite (where the nickel in the laterite typically grades over one per cent). Higher grade cobalt ores can contain up to several per cent cobalt.

Mineral processing

Cobalt processing is complex with a number of saleable products possible from sulfide concentrates to intermediate nickel-cobalt hydroxides and through to cobalt powders and speciality compounds. Saleable products include high purity (>99.8 per cent) cobalt itself. Final cobalt refinery products can take the form of briquettes, powder, ingots and cobalt granules. Refining from an initial cobalt concentrate can be achieved either by electrowinning or pyrometallurgy.

LITHIUM

Demand

Total global consumption of lithium in 2011 is anticipated to be of the order of 25 000 to 27 000 t contained lithium in various products with lithium carbonate the principal form. Annual consumption of lithium carbonate (equivalent) sits around 110 000 to 120 000 t/a. Lithium and its various salts are used in many applications. These include:

- In ceramic glasses to improve resistance to extreme temperature changes.
- To lower process melting points, and as a glazing agent in ceramic and glass manufacture.
- As a catalyst in the production of synthetic rubber, plastics and pharmaceuticals.
- As a reduction agent in synthesising organic compounds.
- In speciality lubricants and greases for working in extreme temperature conditions.
- Importantly with rapid demand growth, in production of both primary and secondary batteries, where lithium has become a key component in lightweight lithium-hydride batteries, used in mobile phones, cameras and notebooks. Lithium-ion batteries are set to benefit from the significant investment in electric cars prompted by global warming concerns.
- In air conditioning and dehumidification systems.

Accelerating demand growth for lithium in future is expected to come from a continued shift towards electric vehicles. Lithium use in batteries is anticipated to be the largest end-use for lithium by around 2015. Major economies, including China, the US and Germany, have all instigated policies that support the development of electric vehicles. These government moves are supported by the major car producers in advancing and developing new generation electric vehicles.

Consumption growth rates for lithium have been around five to six per cent per annum in recent years with suggestions of higher growth rates to come. Total lithium carbonate consumption may rise to exceed 250 000 t by 2020.

Market and pricing

The most commonly traded forms of lithium are mineral concentrates and refined lithium carbonate. There is no international exchange or terminal markets for lithium, lithium carbonate or lithium mineral concentrates, with the market price determined directly by supplier/customer negotiations. Early 2011 prices for lithium carbonate were trading in the range US\$5500 - US\$6000/t, having improved from the US\$5300/t average of 2009. Lithium mineral concentrate prices generally range from US\$120 - 200/t for 2.5 to three per cent Li_2O up to US\$250 - 400/t for six to seven per cent Li_2O content, depending on mineral type (spodumene, petalite, lepidolite), purity and contaminants (principally iron content), and market application. Prices for lithium mineral concentrates used for conversion into chemicals are correlated to, and tend to follow the same trend as, lithium carbonate prices.

Supply

Chile is the leading lithium chemical producer in the world; Argentina, China, and the United States are also major producers. Australia, Canada, Portugal, and Zimbabwe produce of lithium mineral concentrates. Large organisations that supply lithium include Chile's Sociedad Química y Minera (known as SQM), Chemetall, owned by Rockwood Holdings Incorporated of the United States and also FMC Lithium, also of the United States. Toronto-listed Talison Lithium operates the Greenbushes mine in Western Australia. These organisations combine to account for around 85 per cent of supply. China has a number of small lithium carbonate producers, including plants that import feedstock from Australia.

Geology

Producers of lithium basically fall into one of two supplier categories – firstly producers from salar/brine deposits, with South America the main production centre. The key constituents of the brine salts are sodium chloride (common salt), magnesium, potassium and lithium (as chloride and sulfate salts) with boron as a by-product. Secondly, production from lithium-bearing pegmatite deposits, where Australia has significant existing production and future planned production. The principal lithium minerals are spodumene ($\text{LiAl}(\text{SiO}_3)_2$ containing ~7 - 8 per cent Li_2O), petalite ($\text{LiAlSi}_4\text{O}_{10}$) and lepidolite ($\text{KLi}_2\text{Al}(\text{Al,Si})_3\text{O}_{10}(\text{F,OH})_2$).

Key countries of supply

Chile, Argentina and Australia. According to data from the United States Geological Survey, the main producers of lithium in 2009 were Chile (brines, 7400 t Li), Australia (pegmatites, 4400 t), China (2300 t) and Argentina (2200 t), with a total 18 000 t Li, down from 25 400 t in 2008.

Grades

The Greenbushes mine in Western Australia has reported lithium mineral reserves of 31.4 Mt grading 3.1 per cent Li_2O and a combined Measured and Indicated Resource of 70.4 Mt grading 2.6 per cent Li_2O . Ore processing at Galaxy Resources' Mount Cattlin operations will be at a rate of 1 Mt per annum at an average ore grade of 1.1 per cent Li_2O to produce a spodumene concentrate product containing ~6 per cent Li_2O . Salar operations refer to grades in terms of grams per kilolitre or milligrams per litre. In milligrams per litre, lithium brine projects ranges from 400 to 1800 mg/L.

Mineral processing

Processing of brines involves pre-concentration by solar evaporation followed by fractional crystallisation in a processing plant under controlled temperature and temperature conditions.

Processing of pegmatite ore at Talison Lithium's Greenbushes mine is undertaken using two processing plants located at the mining operations. One plant produces technical-grade lithium concentrates (low iron content for ceramic and glass applications), the other produces chemical-grade lithium concentrate. Lithium oxide ore is fed into the processing plants, which upgrades the lithium mineral (spodumene); using gravity, heavy media, flotation and magnetic processes into a range of lithium concentrates for bulk or bagged shipment.

Talison Lithium are currently doubling current production capacity to approximately 740 kt/a lithium concentrate (approximately 110 kt/a of lithium carbonate equivalent LCE), due for completion during Q4 FY2012.

MINERAL SANDS (TITANIUM, ZIRCONIUM, MONAZITE)

Demand

The commodity 'mineral sands' actually refers to a basket of commodities that are typically separated from mineral sand deposits. These include firstly titanium-bearing minerals, which comprise ilmenite (FeOTiO_2), leucoxene (a fine-grained alteration product of other titanium minerals) and rutile (TiO_2). Mineral sands as a commodity class also encompasses the mineral zircon (ZrSiO_4), the ore mineral of zirconium – and finally monazite, a phosphate mineral that has rare earth metal content, including cerium, lanthanum and yttrium.

Given the commodity class is somewhat diverse, it will come as little surprise that uses of the various mineral sand constituent minerals are equally diverse. Approximately 93 per cent of the world's *titanium* is consumed as titanium dioxide pigment, which is then used in the manufacture of paints and as filler materials for paper and plastics. The fact that titanium dioxide is opaque, non-toxic and inert increases its attractiveness in these end uses – as well as in such uses as cosmetics, foodstuffs, inks, toothpaste and sunscreen. The remaining titanium use is as metal, including as golf clubs, and as a flux in welding rods.

The main buyers of titanium dioxide pigment feedstock from mineral sands mining companies are the major chemicals companies, who use the material to manufacture chemical pigments. Of these, the giant Du Pont is the largest buyer with other significant consumers including Tronox Incorporated (formerly Kerr McGee), Tioxide (Huntsman) Limited, Kronos Worldwide Incorporated, Millenium Speciality Chemicals, Kemira (Finland) and Ishihara (ISK).

Global consumption of titanium feedstock is approximately 6 Mt. Global consumption of zircon for 2012 is estimated at 1.4 Mt/a. Market growth for zircon has historically sat around four per cent per annum with three per cent per annum growth for titanium.

Zircon is an extremely hard, refractory mineral with high melting point, regular thermal coefficient of expansion and high thermal conductivity. As such, the mineral is ideally suited to both refractory and abrasive industrial applications. Zircon finds use in ceramics and in foundry/refractory applications. Other zircon end uses include abrasives, glasses, chemicals, metal alloys, welding rod coatings and sandblasting. The main use of zircon in the ceramics sector is as an additive to glazes used on ceramic tiles to provide opacity or 'whiteness'. Minor end uses for zirconium chemicals include catalysts, paper coatings, paint dryers and antiperspirants.

Market and pricing

Titanium mineral concentrate products are traded as feedstock for production of titanium dioxide pigment between producers such as Iluka Resources and their customers, such as Du Pont limited, under negotiated contracts. Contracts can be for several years duration, with volumes fixed for the life of the contract. Buyers and sellers typically have options to vary the traded tonnages, within defined ranges, where sufficient notice has been given. Prices for the contract are agreed upon signing, usually with a defined formula escalator index linked to inflation parameters (such as a consumer price index). The zircon market includes significant spot sales. Titanium pigment feedstock prices are positively correlated to changes in global GDP growth. There is a premium payable for higher grade titanium products. Iluka Resources (ASX:ILU, see Iluka web site) cites 2010 prices for titanium-bearing products as follows: rutile US\$550/t; synthetic rutile US\$450/t; upgraded chloride slag US\$550/t; chloride ilmenite and leucogene US\$100/t; chloride slag US\$400/t. Zircon prices were cited by Iluka Resources as around US\$1000/t at end 2010. Product chemical composition influences prices with iron, aluminium, titanium, phosphate and radiation levels specified in zircon sales.

Supply

Major diversified miners BHP Billiton and Rio Tinto are both mineral sands miners – and act as joint venture partners in the Richards Bay operation in South Africa. Elsewhere in South Africa, South African-listed diversified miner Exxaro Resources mine and process mineral sands from the Namakwa deposits. In Australia, the leading producer is Iluka Resources, the market leader in zircon production.

Geology

Present and geologically-preserved beach sand deposits contain the most important accumulations of heavy mineral sands. Wave action deposits sand on the beach, and the heavy minerals are concentrated when backwash and longshore drift carries some of the lighter minerals such as quartz back into the sea. In essence the sea acts to pre-concentrate the denser minerals such as ilmenite, zircon, monazite and rutile. Furthermore, onshore winds that preferentially blow lighter grains inland can lead to higher concentrations of heavy minerals at the front of coastal dunes. Old 'fossil' shorelines known as strandlines are targeted in exploration for deposits.

Ilmenite is also mined from large deposits hosted by layered mafic rocks in Canada (Rio Tinto), Norway and China.

Key countries of supply

The main producers of zircon in 2009 were Australia (510 kt), South Africa (395 kt) and China (140 kt), with a total estimate 1.23 Mt (source: USGS²), the majority from heavy mineral sands. Major titanium minerals suppliers are Australia, South Africa and Canada.

Grades

Typical heavy mineral sand deposits grade a combined three per cent through to 25 per cent. The economics of a deposit is controlled by the relative ratio and composition of the basket of heavy mineral sands that comprise the resource. High-grade zircon mineral sands attract a market premium.

Mineral processing

Mineral sands are mined using open cut mining methods and where appropriate, dredging. Initial mineral processing is undertaken using both wet concentration methods and dry mineral separation. Titanium dioxide feedstock products generated from ilmenite and leucoxene by miners include sulfate grade ilmenite (TiO₂ 35 - 58 per cent), sulfate grade slag (TiO₂ 75 - 80 per cent), chloride grade ilmenite (TiO₂ 58 - 62 per cent), chloride slag (TiO₂ 85 - 87 per cent) and synthetic rutile (TiO₂ 90 - 95 per cent). Rutile (TiO₂ 90 - 96 per cent) is also sold directly as titanium dioxide pigment feedstock. Commercial production of titanium metal involves the chlorination of titanium-containing mineral concentrates to produce titanium tetrachloride (TiCl₄), which is reduced with magnesium (Kroll process) or sodium (Hunter process) to form a commercially pure form of titanium metal.

Zircon is separated using electrostatic, magnetic and gravity methods. Zircon grains are cleaned to remove clay contaminants using acid and heat treatments. In some instances, the zircon is calcined at high temperature to whiten the finished product and enhance opacifier properties.

MOLYBDENUM

Demand

Historically, molybdenum demand has shown a strong growth rate, primarily fuelled by the rapid increases in Chinese industrial growth. Molybdenum demand continues to be driven largely by the steel sector, which represents close to three quarters of global off-take. Molybdenum in steels adds to strength, toughness and wear resistance. China continues to be a key source of growth, now accounting for approximately 35 per cent of global consumption of molybdenum. Indeed, China's role in determining molybdenum demand may become even more significant as the demand from more mature economies slows down. The major steel-making economies across Western Europe, plus Japan and the United States are the other main consumption regions. Beyond stainless and low alloy steels, other molybdenum uses include super-alloys, chemicals and castings. Molybdenum chemicals are used in applications such as catalysts, lubricants, corrosion inhibitors, smoke suppressants and pigments.

Market and pricing

Molybdenum is sold in oxide form to steel mills, or can be processed further into high purity oxide for use in high value niche products. Most molybdenum, however, is processed into

2. The US Geological Survey publishes minerals statistics periodically in on-line open file reports.

mineral concentrates (molybdenite) for initial sale from the mine site to the smelters or oxide producers. In 2010, the LME launched its molybdenum oxide contract.

Molybdenum prices are renowned for their volatility. Historical prices prior to the GFC slowdown averaged around US\$30/lb in 2007 and 2008 before collapsing to US\$12/lb in 2009. When prices rise, copper-molybdenum mines switch their production schedules to take advantage of the raised molybdenum price – thereby adding to supply and alleviating price spikes. LME cash and three-month molybdenum prices can be viewed at the Base Metals web site with contract prices up to 15 months forward at the LME web site. Indicative molybdenum concentrate prices can be viewed at the Metal Pages web site.

Supply

Around half of molybdenum production is sourced as a by-product from copper mines, notably in the United States and Chile. Main product molybdenum production is dominated by Chinese mines. In-ground resources of molybdenum are led by China, followed by the United States and Chile. Codelco, Chile's national copper company is a significant molybdenum producer – from its mines at Andina, El Teniente, Chuquibambilla and El Salvador. Chile's Antofagasta Minerals also produces molybdenum from its Los Pelambres mine. Freeport and Grupo Mexico are also significant producers. Freeport's assets include the Henderson mine and also the Climax molybdenum mine in Colorado, previously the world's largest molybdenum producer.

Geology

Molybdenum is not found as a native metal. It is typically found and mined as molybdenite, molybdenum sulfide (MoS₂). The sulfide occurs in disseminated form commonly associated with copper mineralisation in porphyry style deposits.

Key countries of supply

Global production of molybdenum is concentrated amongst relatively few countries, with China, United States, and Chile the standout suppliers. Significant additional molybdenum is sourced from Peru, Canada, Mexico, Armenia, Iran and Mongolia. The United States molybdenum mines are in Colorado, Idaho, Nevada and New Mexico. US Copper-molybdenum mines are in Arizona, Nevada, New Mexico, Montana and Utah.

Grades

High-grade primary molybdenum mines can exceed one per cent in grade. Lower-grade polymetallic deposits, for which molybdenum is produced as a co-product or by-product, typically with copper, can be below 0.1 per cent (1000 ppm) molybdenum.

Mineral processing

Primary ores are crushed and ground then froth floated to produce a concentrate. Concentrate is then roasted to liberate a molybdenum oxide from the sulfide, which can then undergo sublimation to enhance purity for production of lubricants, molybdenum metal and chemicals. Copper-molybdenum mixed ores are also crushed, ground and floated with a high-copper and low-copper concentrate stream produced. The low-copper stream is roasted to release the molybdenum whilst the high-copper stream is first leached before the molybdenum is roasted. Oxide can be converted to ferromolybdenum (used by foundries when adding molybdenum to cast iron and steels) else sold as oxide powder or briquettes.

Significant industry development

Merlin, the world's highest grade molybdenum and rhenium deposit, was discovered in Queensland by Ivanhoe Australia in late 2008. The current Mineral Resource estimate released in 2010 consists of an Indicated Mineral Resource of 6.5 Mt at 1.3 per cent molybdenum and 23 g/t of rhenium and an Inferred Mineral Resource 0.2 Mt at 0.9 per cent molybdenum and 15 g/t of rhenium. The high-grade nature of the Merlin deposit is exceptional; being approximately seven times greater than the highest-grade molybdenum mine currently operating, when rhenium credits are included. Mine development commenced during 2011 with concentrate production planned from Q3 2013 and first saleable production in Q1 2014. Average production of approximately 5030 t of molybdenum and 7.2 t of rhenium per year based on a roaster producing separate molybdenum, as molybdenum trioxide (MoO_3), and rhenium, as ammonium perrhenate (NH_4ReO_4), products. Overall molybdenum metal recoveries estimated by Ivanhoe Australia are approximately 84.5 per cent and rhenium 80.9 per cent.

NIOBIUM

Demand

Some 85 per cent of all niobium is used in the steel industry as an additive to make high strength low alloy (HSLA) steel products. The more sophisticated 'high-end' of the steel market will add around 57 grams of niobium into every tonne of steel to increase the tensile strength of steel products. Other attributes are its high temperature strength and anti-corrosive properties. Niobium in steel products is used for major construction projects, oil and gas pipelines and automotive components. The closest metal to niobium for performance similarity is vanadium, which is largely substitutable.

Presently, only ten per cent of steel products contain niobium, and it is regarded as the 'high-end' part of the steel market. Western steel production contains a greater percentage of niobium steel products than the steel production from developing nations. In time, however, this ten per cent figure is expected to grow substantially, driven by two related factors: firstly, the increasing sophistication of the steel industries in the high-growth developing nations and secondly, through regulation. Building, equipment and automobile performance specifications will increasingly become mandatory in the use of higher-end steel products. In line with this trend, China is the main growth area for niobium demand.

Market and pricing

Niobium is not traded on a commodity exchange: ferroniobium (FeNb_{65}) is the principal traded product sold under buyer-seller negotiated contracts. A benchmark price is set by the main producer, CBMM.

Indicative prices for ferroniobium are available from the Metal Pages web site.

Supply

CBMM is a privately-owned Brazilian group that owns the Araxa mine in Brazil. With the largest niobium deposit in the world, it supplies around 75 - 80 per cent of the global market. There are two other significant producers, Anglo American (from its Catalao mine, Brazil) and IAMGOLD (Niobec mine, Canada). Each mine contributes approximately seven per cent of additional market share.

Geology

Niobium resources and production are related to two styles of mineralisation: primarily from pyrochlore mineralisation ($(\text{Na,Ca})_2\text{Nb}_2\text{O}_6(\text{OH,F})$) hosted in carbonatite intrusive complexes, and from tin-tantalum-columbite mineralisation ($(\text{Fe, Mn})(\text{Nb, Ta})_2\text{O}_6$) as a by-product of pegmatite mining. Niobium is never found as the free element. Minerals containing niobium usually also contain tantalum and are commonly associated or contain uranium and thorium-bearing mineral phases that may impact on marketability of mineral concentrates.

Key countries of supply

Brazil.

Grades

The Araxa reserve grade at 2.5 per cent Nb_2O_5 is significantly higher than other operations (1.2 per cent Catalao, 0.6 per cent Niobec), which reflects in relatively low production costs and supports 'value added' processing to ferrovanadium. Both factors provide a CBMM with a dominant market position, which, along with a relatively small market size, creates barriers to entry for new producers.

Mineral processing

Major producer CBMM reports the following processing steps at their niobium concentrator: wet grinding, magnetic-process separation, deliming and flotation.

- Step 1: wet grinding separates pyrochlore crystals from ore. Ore particles are reduced to less than 0.104 mm.
- Step 2: magnetic separation eliminates magnetite, a mineral with a high phosphorous content.
- Step 3: deliming removes fractions below 0.005 mm in cyclones of 25 mm.
- Step 4: flotation concentrates pyrochlore in flotation tanks where pyrochlore particles are mixed with chemical reagents and trapped by air bubbles introduced at the bottom of the tank. The buoyant concentrate contains 60 per cent Nb_2O_5 . The underflow is transferred to a tailings disposal dam.

The pyrochlore concentrate is then refined using a CBMM-developed pyrometallurgical process, which includes pelletising and sintering the concentrate, followed by reductive melting (dephosphorisation). Ferroniobium (FeNb_{65}) is produced using aluminothermic reduction in an electric arc furnace. The refining of niobium to FeNb_{90+} and niobium metal is usually by electron beam melting in vacuum arc furnaces.

POTASH

Demand

The world potash industry exists primarily to supply fertilisers that contain potassium, one of the three main plant nutrient elements, which means that potash producers depend for the vast majority of their sales (~90 per cent) on the demand from agriculture. Potash fertilisers help to increase global crop production to meet the requirements of the world's growing population; including the increasing demand for higher value foodstuffs such as meat and fruit that require intensive use of fertilisers. The term 'potash' generally applies to

a range of potassium minerals and chemicals, but particularly to potassium chloride. This substance, often known as MOP ('muriate of potash') or by its chemical formula (KCl) is the most common potassium fertiliser.

Non-fertiliser use of potassium chloride represents less than ten per cent of global consumption, but in certain areas it can be much more significant. The most common chemical derivative of potassium chloride is potassium hydroxide, which is produced on a large scale primarily in Western Europe (30 per cent of global capacity), the United States (30 per cent) and Japan and South Korea (20 per cent). KCl is also used as an additive in drilling mud, most significant in North America and the Middle East.

Market and pricing

Potash is traded under buyer-seller contracts. China and India have traditionally purchased much of their potash via 12-month contracts, though some suppliers are pushing for a shift to greater use of quarterly and spot sales as used elsewhere. Two large potash export trade associations, Canpotex and BPC, manage export sales from Canada and Russia/Belarus respectively. The members of Canpotex are Agrium, Mosaic and PotashCorp, with the BPC members being Uralkali and Belaruskali.

Since the 1960s, the trajectory of potash prices has been an unexciting one, aside from peaks in the mid-1970s and early 1980s. There was a lengthy period of declining prices (in real terms) from the late 1980s onwards, leaving prices at around \$120/t until a major bull-run began in 2003. That run ended with spot prices touching \$1000/t in 2008. Since then, prices have fallen, but remain higher in real terms than at any point before 2007.

Supply

There is very little overlap between areas of high potash production and those of high potash consumption (China, India, United States and Brazil); therefore, the majority of the world's potash production is exported.

Ten organisations control 95 per cent of the total global capacity, with the three largest accounting for half of the total. The biggest producers of potassium chloride are PotashCorp and Mosaic in North America and the state-controlled potash industry of Belarus.

Geology

The predominant ore mineral for potash mining is sylvinite, which contains a mixture of sylvite (potassium chloride) in combination with halite (rock salt) and smaller amounts of other evaporite minerals and clay. Operations are mainly underground conventional mines utilising bulk mining methods similar to underground coal mines (as the ores occur in relatively flat lying seams), with a small number of solution mines also in production. The remaining capacity comes from operations that treat natural brines, usually through solar evaporation, to obtain minerals such as carnallite ($\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$) from which KCl can be extracted.

Key countries of supply

Two thirds of the current capacity total is located in just three countries – Canada, Russia and Belarus. This figure rises to over 90 per cent when the next three largest producing countries are added; namely Germany, Israel and Jordan. Smaller producing nations include the United States, Brazil, China, Chile, the United Kingdom and Spain.

Grades

Typical resource and ore grades in Canadian potash operations are 20 - 25 per cent K_2O (33 - 42 per cent KCl). The large undeveloped Udon South potash deposit in NE Thailand is reported at 255 Mt at 23.5 per cent K_2O (equivalent to ~39 per cent KCl). Fertiliser grade KCl typically contains 60 per cent potassium nutrient (' K_2O ').

Mineral processing

Potassium chloride is extracted from potash minerals via flotation and thermal dissolution, either separately or integrated into the same flow sheet. Some producers also employ HMS (heavy media separation) or electrostatic separation as part of their treatment schemes. Flotation is favoured because of its simplicity and low energy requirements.

RARE EARTH METALS

Demand

Rare earth elements (REE) and rare earth oxides (REO) are group terms that encompass 17 chemical elements of the periodic table. Until recently these elements were very far from household names – known only to industry participants and to geochemists and chemical engineers. However, their collective strong price appreciation in recent years, coupled with the fact that Australia is well-endowed with deposits of these elements has meant the rare earths have now become better known amongst the investment community. For the record, the 17 elements are scandium (Sc), yttrium (Y) and 15 elements collectively termed the lanthanides. The lanthanides comprise the following elements that sit between numbers 57 and 71 on the Periodic Table inclusively: lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb) and lutetium (Lu). The lanthanides are further classified into 'light' and 'heavy' rare earths. The six 'light' rare earths are ordered by atomic number and are lanthanum, cerium, praseodymium, neodymium, promethium and samarium, with the remainder of the metal suite classed as 'heavy' rare earths.

Consumption of the REE underpins a broad set of new materials technologies required to sustain the needs of modern society. Specifically, REE consumption is one of the enablers of the global trend towards energy efficiency through lower energy consumption. In this respect, rare earths are consumed in compact energy-efficient fluorescent lights and in hybrid vehicles. REE consumption is also aligned to the global trend towards environmental protection through lower emissions. REE uses in wind turbines, in auto catalytic converters and in diesel additives apply in this context. Furthermore, increasing REE consumption is an enabler to the global trend towards smaller, yet more powerful, digital technology. REE end-uses in flat panel displays, disk drives and digital cameras are key facilitators of this technology trend.

The outlook for REE consumption is considered positive across a suite of end-use segments. That is, REE use in automotive pollution control catalysts, in fluid catalytic cracking (FCC) catalysts for petroleum refining, in permanent magnets, and in rechargeable batteries are all expected to continue to increase as future demand for conventional and hybrid automobiles, computers, electronics, and portable equipment grows.

Global consumption by end-use segment in 2010 is estimated at 136 000 t of REO with approximate consumption by segment as follows (totals and percentages are rounded). REO

magnets are the principal end-use by volume (25.7 per cent; 35 000 t) followed by FCC catalysts (15.7 per cent; 21 300 t), polishing powder (14.0 per cent; 19 100 t), battery alloys (13.7 per cent; 18 600 t), other metallurgical alloys 8.6 per cent; 11 700 t), auto catalysts (6.6 per cent; 9000 t), glass additives (5.7 per cent; 7800 t), phosphors (5.8 per cent; 7900 t) and other uses (4.2 per cent; 5700 t). Global consumption by value in 2010 is estimated at US\$7.8 billion. Magnets are also the principal end-use by value, estimated at 38 per cent.

As research and technology continue to advance the knowledge of rare earths and their interactions with other elements, the economic base of the rare-earth industry is expected to continue to increase.

New applications are expected to continue to be discovered and developed, especially in areas that are considered essential, such as in energy and electronic technology/defence. Selected segments for increased rare earth use include fibre optics, medical applications encompassing dental and surgical lasers, magnetic resonance imaging, medical contrast agents and medical isotopes. Future growth potential is also projected for rare-earth alloys employed in magnetic refrigeration.

Magnets and battery alloys are amongst the strongest drivers of consumption growth. By end-use, annual growth rates are estimated at 15 per cent for battery alloys, 12 per cent for magnets, ten per cent for polishing powder, eight per cent for auto catalysts phosphors and other uses, four per cent for FCC catalysts, two per cent in metallurgical alloys and zero per cent for glass additives. Global consumption in 2011 is anticipated at around 150 000 t of combined rare earth metals. Global REO consumption by 2014 is anticipated to increase to around 190 000 t, an overall growth rate of nine per cent per annum. Given the high technology focus for most end uses, consumption is anticipated to double over the next decade to 300 000 t.

Market and pricing

The sale and purchase of REO concentrates, oxides and value-added products is conducted through confidential party to party contracts and no terminal metals market or exchange exists for rare earth metal trading. Prices that are quoted in the public domain for the various metals should therefore be considered indicative. Specific sale prices reflect a number of factors include product specifications, quality, contract duration, origin of supply and associated supply risks. REO products are typically sold in standard package quantities of between 5 - 20 kg.

Prices vary by orders of magnitude between the individual rare earth elements. Relatively lower value metals include the likes of gadolinium and yttrium (early 2011 prices of ~US\$10/kg) ranging up to the high value metals such as terbium and europium (early 2011 indicative prices of ~US\$600/kg). Lynas Corporation (ASX: LYC) post the respective rare earth oxide prices at their web site with prices quoted in US\$/kg on an FOB China basis and for 99 per cent purity product.

Metals Pages post prices for the following:

- cerium metal and oxide
- dysprosium metal and oxide
- europium metal and oxide
- gadolinium and oxide
- lanthanum metal and oxide
- neodymium metal and oxide

- praseodymium metal and oxide
- samarium metal and oxide
- terbium metal and oxide
- yttrium metal and oxide.

Supply

China dominates supply in REO, both for its domestic consumption and in exports. Production originates from iron ore mining at Baotou, Inner Mongolia, NW China and from clay rare earth deposits at Long Nan, Jiangxi, SE China. Total China production capacity is in the order of 100 000 t total REO with western capacity in 2010 adding a further 10 000 t. The Chinese export policy is closely watched by the market as ex-China supply has been restricted since 2010. New western world supply is being commissioned with a large number of explorers now targeting the discovery of new projects. Lead times for new projects not already at feasibility stage will be between five to ten years. Processing of rare earths requires tight environmental regulation as waste products can be toxic.

Geology

Rare earth elements occur in a variety of geological settings. These include iron-rich hydrothermal alteration and mineralisation (eg Bayan Obo, China and Olympic Dam, Australia), carbonatite intrusions (eg Mountain Pass, USDA and Mount Weld, Australia), peralkaline syenitic igneous rocks, hydrothermal veins, within weathered clay deposits, in placer deposits, in pegmatites and in skarns.

Key countries of supply

China dominates global rare earth metal production. India and Russia contribute minor supply. The United States is looking to recommence production from the historical Mountain Pass rare earths mine.

Grades

In Australia, Lynas Corporation's Mount Weld stands out as the highest grade rare earth metals deposit at an overall grade of eight per cent total rare earth oxides (TREO), with parts of the deposit exceeding ten per cent in grade. Typical deposits sit at around two to four per cent TREO globally.

Mineral processing

Mine production typically produces a rare earth mineral concentrate via flotation, thickening and filtration of crushed ex-mine ore that needs to undergo further complex chemical processing and separation in order to produce a rare earth oxide product. Metallurgical plants can also produce metal end product else rare earth alloys for sale to manufacturers who then produce finished products such as rare earth oxide magnets.

TANTALUM

Demand

Tantalum is used in diverse high technology applications. It is resistant to corrosion, has a low thermal coefficient of expansion, and a high dielectric constant, so its main uses are

in capacitors (eg for consumer electronics including mobile phones), chemical plant and equipment, aviation turbine blades and, as tantalum carbide, for cutting tools. The electronics industry consumes 60 per cent of the world's tantalum production. Leading commercial consumers are HC Starck GmbH (part of German conglomerate Bayer AG), as well as Cabot Corporation (United States), Ulba OJSC (Kazakhstan), Mitsui-Kinzoku (Japan) and Ningxia Non-Ferrous Metals (China).

Market and pricing

The majority of tantalum is sold under long-term off-take agreements between consumer and supplier. Other material is provided on spot markets via intermediate traders.

Indicative prices for tantalum can be viewed at the Metal Pages web site. The spot market price of tantalum increased substantially in 2010 from approximately US\$40/lb in January to a price of approximately US\$130/lb at December 2010.

Supply

Historically, the principal source of tantalum was tin mining where tantalum was extracted as a by-product; however, by the 1990s, the principal source of tantalum came from main product tantalum operations. Western Australia's Greenbushes and Wodgina mines together with Brazil's Nazareno mine, owned by Metallurg, are amongst the largest tantalum mining centres in the world. Wodgina and Greenbushes are now owned by Global Advanced Metals (not listed on the ASX). The Wodgina mine was closed during the GFC as tantalum prices turned down and conflict tantalum from Africa flooded supply. In January 2011, operations at Wodgina were restarted given the improved market conditions.

Tantalum supply also originates from artisanal production of tantalum-bearing minerals (notably in Central Africa), from synthetic concentrates produced from tin-slugs and accumulated tin-mining wastes, from tantalum stocks/inventory, from intermediate materials such as tantalum oxide, and from recycled consumer and processor scrap and other secondary materials. Scrap tantalum from recycling accounts for about 20 per cent of total supply each year.

Geology

Tantalum mineralisation occurs in pegmatite deposits in the mineral tantalite $[(\text{Fe},\text{Mn})(\text{Ta},\text{Nb})_2\text{O}_6]$, where it is often associated with tin, beryl and lithium mineralisation, and in granite related deposits associated with tin and tungsten mineralisation. Tantalum also occurs with niobium mineralisation in carbonatite deposits in minerals such as pyrochlore and microlite $(\text{Na},\text{Ca})_2\text{Ta}_2\text{O}_6(\text{O},\text{OH},\text{F})$.

Key countries of supply

The major primary tantalum mine producers are Brazil and Australia. The largest secondary tantalum producer (waste and scrap) is China. Canada is the major tantalum producer in North America. Tantalum Mining Corporation (Tanco) owns a mine in Lake Manitoba. In Malaysia and Thailand, the tin industry still provides tantalum as a component of tin slag, a by-product of the smelting of cassiterite ore concentrates for tin production. Africa produces 25 per cent of the world's tantalum ore. The tantalum market includes material supplied from small scale mines in the Democratic Republic of Congo (DRC), Rwanda, Uganda and Burundi and sometimes referred to as 'conflict tantalum'. Locally, tantalum-bearing minerals in Central Africa are referred to as 'coltan'.

Grades

Mined grades of tantalum in Australia have historically been reported between 200 and 500 ppm Ta_2O_5 . Galaxy Resources' (GXY) Mount Cattlin project contains by-product tantalum at grades of around 150 ppm Ta_2O_5 .

Mineral processing

Production of tantalum mineral concentrates is typically by conventional gravity separation methods including hydraulic jigs, spirals and vibratory tables. Fine grained tantalum-bearing minerals can be recovered using froth flotation, though recoveries are generally poor at fine particle sizing <70 micron. The extraction and refining of tantalum, including the separation of tantalum from other metals in tantalum-containing mineral concentrates involves treatment with a mixture of hydrofluoric and sulfuric acids at elevated temperatures. Tantalum metal powder is produced by the sodium reduction of the potassium tantalum fluoride in a molten salt system at high temperature. The conversion of metal powder to ingot and for processing into various metallurgical products is undertaken using vacuum arc melting or electron beam melting of the Ta powder.

TUNGSTEN

Demand

Tungsten is used as cemented carbides for cutting tools and drills given its extreme hardness; these uses contributing over half global demand by end use sector. Steel alloy demand contributes the next largest end-use at 20 per cent – with the metal's well-known application in lamp filaments only a small contributor. Global consumption is estimated at around 70 000 t tungsten content for 2011.

Market and pricing

Traded both in concentrate form and as finished metal. Indicative price movements are reported weekly and are widely available. As there is no terminal market for any tungsten product, pricing is settled through direct buyer-seller negotiations and is not wholly transparent. Indicative prices for tungsten products, including oxide, carbide powder and concentrates can be viewed at the Metal Pages web site. The tungsten industry did not escape the effects of the 2008 - 2009 global recession. Chinese mine production cutback late in 2008 and prices for tungsten intermediate products fell from levels that had persisted since 2005.

Supply

China is the name of the game in both tungsten supply and demand. Daylight comes second on both counts. Various estimates of China's mine output exist – and a notable proportion of China's production goes unreported. The main Chinese provinces that produce tungsten are Jiangxi and Hunan, with Guangxi, Yunnan, Henan and Guangdong provinces producing lesser amounts. China's strategy in tungsten, not unlike other metals, is to focus upon growing market position in downstream processing. As such the export of intermediate tungsten products is discouraged, although export quotas still total over 8 Mt, with tungsten oxides and APT (ammonium paratungstate) the main contributors. Ore and concentrate exports are not permitted. Major producers include Minmetals Nonferrous Metal Corporation, Jiangxi Rare Earth and Rare Metals Tungsten Group, Jiangxi Tungsten Industry Group, Hunan Nonferrous Metals Group, Xiamen Tungsten Group and Zijin Mining Group.

China is playing a strategic game on the tungsten supply-side – a position afforded by a predominant market position. Mine depletion effects, coupled with government restrictions such as mining quotas (since 2002), suspension of new project licences (since 1999), export tariffs and restrictions on foreign investment are set to act as dampeners to Chinese production growth reaching its full potential.

Recycling is important to the supply-demand balance – and responds to price. Some 30 per cent of tungsten consumed in the production of tungsten products is sourced from scrap.

Geology

Tungsten does not occur as native metal. The main commercial ores are wolframite ((Fe,Mn)WO₄) and scheelite (CaWO₄). Scheelite ores dominate China's reserves base – with wolframite and mixed ores comprising less than 30 per cent: Wolframite ore and concentrates can attract a price premium over scheelite. Tungsten mineralisation commonly occurs in hydrothermal veins, greisen, and skarn style deposits related to granitic intrusive rocks and is often in combination with tin mineralisation, where the metals form co-products.

Key countries of supply

China is the main game: Other producers include Russia, Austria, Portugal, Bolivia, Peru, Myanmar, Kazakhstan and Uzbekistan. For perspective, whilst Australia sees a number of emerging companies seeking to enter the market and mine tungsten ores, China already has over 200 mines, led by the Jiangxi province (and those are just the ones that report into official figures).

Grades

Typical resource grades lie between 0.1 - 0.3 per cent WO₃ depending upon the lower cut-off grade applied in the resource estimation. High-grade tungsten resources containing one to two per cent WO₃ are reported at several wolframite vein deposits; however, production capacity is limited due to narrow underground mining widths.

Mineral processing

Tungsten has a value chain that starts with production of tungsten mineral concentrate as the first saleable product. Production of concentrates is typically by conventional gravity separation methods including hydraulic jigs, spirals and vibratory tables. Fine grained tungsten-bearing minerals can be recovered using froth flotation, though recoveries of scheelite are notoriously poor (<50 per cent) at fine particle sizing <70 micron due to sliming.

In order of increasing value-add, the downstream tungsten products are then Ammonium Paratungstate (APT), tungsten metal powder, ferrotungsten, tungsten carbide powder and tungsten products used for industrial (and consumer) applications. Marketable tungsten concentrates contain 65 - 70 per cent tungsten oxide (WO₃) with penalties for contaminant Mo, Cu and As. APT is the typical precursor to most downstream tungsten products, converted into elemental tungsten powder via thermal decomposition and to other tungsten compounds by chemical processing. APT is calcined through oxidation to produce tungsten trioxide or tungsten blue oxide, which are then reduced using hydrogen to derive tungsten metal powder (W powder). Ferrotungsten is made from tungsten ore concentrates and also W powder and typically grades 75 - 85 per cent tungsten. The thermal reaction of W powder with high-purity carbon forms tungsten carbide powder (WC powder).

URANIUM

Demand

Demand for uranium is almost solely driven by nuclear reactor requirements for electricity generation, with other uses (chiefly research, medical and military applications) representing just five per cent of total consumption. The global market in 2011 sat at approximately 90 000 t U_3O_8 equivalence of which approaching 70 000 t is fed from mine supply and 20 000 t from secondary sources of uranium, including ex-military sources. Uranium conversion and enrichment facilities are most notably located in Russia, the United States, France, Canada and the UK, with smaller facilities in Japan, China and Brazil. Uranium demand originates from those countries for which nuclear energy comprises a significant proportion of the national energy mix, notably the United States, France, Japan, Russia, South Korea, the United Kingdom, Ukraine, Canada, Sweden with China a fast growing market as Beijing follows a path of nuclear power station build. Nuclear power capacity will therefore grow significantly over the next decade despite the demand shock of the 2011 Fukushima incident. The disaster at the Fukushima Daiichi nuclear power plant in Japan has nevertheless had a profound impact on the uranium market. The disaster was classified as a major accident on the International Nuclear and Radiological Event Scale and is the worst nuclear accident of its kind since Chernobyl. It was triggered by the Tōhoku earthquake and tsunami on 11 March 2011, which was one of the most powerful recorded earthquakes in the world since modern record-keeping began. A number of safety reviews have been undertaken at the national and international level since the disaster, with numerous countries conducting an assessment of their energy policies. With the exception of Germany, most significant countries that generate electricity using nuclear reactors have reaffirmed that they wish to keep nuclear power as part of the energy mix – conditional on utilities implementing any additional safety measures that may be considered prudent following the events in Japan.

Energy security is a key driver of the rise of uranium as a preferred fuel for base load power in China and India. Greenhouse gas emission reduction obligations and high hydrocarbon prices are helping to shape public opinion of nuclear power in the developed economies, countered by the environmental challenges posed by waste management and by the threat of radiation leakage witnessed in the negative public reaction highlighted by Fukushima.

China is expected to become the growth engine of the uranium market. There are currently 30 reactors under construction and more than 150 in the planned and proposed stages

Research by CRU Group suggests that annual global demand is expected to increase by 78 837 t U between 2013 and 2035 corresponding to a compound annual growth rate (CAGR) of 3.6 per cent over the period. Growth is expected to be stronger between 2010 and 2020 at a CAGR of 4.6 per cent.

Market and pricing

Over 80 per cent of uranium (yellowcake, U_3O_8) is supplied under multi-annual contracts (usually three to seven years forward) with both primary and secondary producers. A large proportion of long term contracts have pricing mechanisms linked to the spot market based on prices published by TradeTech and Nukem. There is no terminal clearing market for uranium, but very small quantities of financially settled U_3O_8 futures are sold on the NYMEX and funds have been created so investors can directly hold inventories.

Prices of U_3O_8 were relatively flat during the 1990s, with real prices largely remaining under US\$20/lb, a reflection of plentiful secondary supply, and utilities maintaining

significant stockpiles. Since the turn of the century, spot prices have taken a more bullish turn, rising sharply in 2004 following an increase in proposed/planned reactor builds. The return to nuclear power, dubbed 'the nuclear renaissance' can be attributed to a number of important issues facing the energy markets that have become increasingly apparent in the last decade. A speculative price spike reached a peak of US\$136/lb in June 2007 as utilities had allowed stockpiles to erode and there were concerns over the continuity of supply. In reality, most of the near-term supply concerns were unfounded and largely accredited to speculation in the market. Given that most U_3O_8 is sold under long term contracts, most producers missed out on capturing the full value of the recent price spike although there is a growing trend stronger influence of spot prices in contract pricing formulae. In 2011, spot prices have predominantly sat around US\$50/lb with contract prices higher at US\$60 - 80/lb.

Research by CRU Group suggests that prices to 2014 are expected to remain between \$50 and \$60/lb. Post 2014, CRU group forecasts some upward pressure on prices as new higher cost projects are required to meet rising demand triggering prices up to \$70/lb in real terms.

Supply

In addition to primary mine production of yellowcake as a source, reactor fuel can also be derived from secondary sources such as ex-military weapons-grade uranium and plutonium as well as recycled uranium and plutonium from spent fuel (known as mixed oxide fuel, or MOX). Primary supply from mines involves a number of extraction technologies. *In situ* leaching (ISL) (or solution mining) does not directly remove the uranium-bearing ore from its geological deposit. Instead, an acid or alkaline solution is injected through wells into the ore deposit, and the resulting uranium-rich liquid is pumped out to the surface for mineral recovery. More traditional mining methods include drilling and blasting the uranium ore out of the ground through underground and open pit mining. Uranium is the main product at most mines; however, is also sometimes mined as a by-product to other metals, such as at BHP Billiton's Olympic Dam mine in South Australia.

Geology

Uranium occurs in a wide variety of geological settings and in various ages of rocks. Uranium does not occur in its native state. The main ore minerals for uranium are pitchblende, carnotite, autunite and torbernite. Amongst the uranium deposit-types, sandstone-hosted, unconformity-related, calcrete-hosted and iron-oxide-uranium-copper-gold (IOUCG) deposits are noteworthy, with all of these styles present within Australia. The giant Olympic Dam deposit, with a uranium inventory some 20 times that of the next largest uranium resource in the world, is an IOUCG mineral deposit.

Key countries of supply

For the last decade, Canada and Australia have been the world's largest uranium producers. Countries experiencing growth in uranium production over the last five years include Kazakhstan, Australia, the United States, as well as Namibia and Russia. Kazakhstan became the world's largest producer of mined uranium in 2009 at around 35 per cent of supply.

Grades

There is a clear reduction in quality of uranium assets between current mines and potential new projects in terms of grade. As a guideline, 1 kg U_3O_8 /t and above can be considered high grade, whereas grades below this benchmark can be regarded as of lower grade.

Metallurgy

Mine output is typically a yellowcake product with a concentration of U_3O_8 of between 70 - 90 per cent. Specifically, the mine to yellowcake process is as follows – with local variants between mines. Uranium ore is reduced by crushing and grinding to a fine particle size (typically between 20 and 150 micrometres) to enable leaching of the uranium. Ore slurry is then leached, often using sulfuric acid with an oxidiser such as pyrolusite (manganese dioxide); or sodium chlorate; or hydrogen peroxide. The dissolved uranium solution is then separated from the undissolved solids in a liquid-solid separation stage using CCD (counter-current decantation) thickeners. The uranium solution (pregnant liquor) is then filtered through sand filters, purified and upgraded via either solvent extraction or ion exchange (SX or IX), ending up with a higher grade uranium solution from which the uranium product is precipitated and thickened, then dried and packed, in 205 L drums, for export.

Uranium is converted into a gas UF_6 then enriched. Enrichment involves increasing the proportion of the fissile U-235 isotope from its level of 0.711 per cent in natural uranium to the level required for the reactor fuel, typically in the range of 3.5 per cent to four per cent. Enrichment also produces tails material, which is depleted in U-235 content (depleted uranium).

VANADIUM

Demand

Approximately 85 per cent of vanadium is consumed by the steel industry as an alloying metal for use in automobiles and construction materials. The intensity of use of vanadium in steels has gradually increased in recent years as construction standards require the added hardening properties that vanadium imparts to the finished steel. Beyond steel, vanadium is used in speciality metals alloys, (vanadium-lithium) batteries and in chemicals. Vanadium chemicals are used principally as catalysts in the production of fertilisers. World consumption of vanadium is of the order of 65 000 t contained vanadium (in pentoxides and ferrovandium).

Market and pricing

Vanadium pentoxide is traded by negotiated contract between buyer and seller. The pricing of contracts for vanadium pentoxide is generally on a short-term spot basis. Vanadium prices are typically quoted for its principal saleable products: vanadium pentoxide (V_2O_5) and ferrovandium (FeV). Prices are not fully transparent, being determined contractually between buyers and sellers, with indicative prices cited by metals journals, web outlets and analysts. Since the iron and steel industry, via ferrovandium, is the major consumer of vanadium, high prices tend to correlate with periods of heightened steel demand. Indicative prices for vanadium pentoxide and ferrovandium can be viewed at the Metal Pages web site.

Prior to the impact of the GFC, V_2O_5 prices averaged US\$14.00/lb of V_2O_5 (in April 2008) before falling as low as US\$3.60/lb in April 2009 during the economic downturn. Late 2011 vanadium pentoxide prices traded at around US\$6.50/t, however, fell back below US\$5.50/lb in 2012. Ferrovandium (FeV) prices followed a similar trend to pentoxide.

Supply

Xstrata Plc has a strong presence in the vanadium market, operating the Vantech mine in South Africa. Global iron and steel company Evraz is also a major vertically integrated vanadium producer. Evraz controls assets including Highveld Steel and Vanadium

Corporation in South Africa, Vanady-Tula in Russia, Nikom in the Czech Republic and also Strategic Minerals Corporation in the United States.

Geology

Vanadium occurs in combination with uranium in some rock-types, notably in oil shales and occurs also in phosphate-bearing rocks. Vanadium ores are also exploited from vanadium-bearing magnetite zones within discrete layers of igneous intrusions. The association of vanadium and magnetite allows exploration for vanadium using airborne magnetic methods where the magnetite mineralisation creates a detectable magnetic anomaly.

Key countries of supply

Vanadium Pentoxide: South Africa, Russia and China. Ferrovandium: South Africa, Japan and Germany/Austria.

Grades

Low grades are below 0.5 per cent V_2O_5 ; typical grades are 0.5 per cent to one per cent V_2O_5 but can rise to several per cent V_2O_5 .

Metallurgy

Mining of vanadium-bearing magnetite ore is followed by crushing, screening and grinding with magnetic separation of the vanadium and titanium content from gangue silica and calcium bearing contaminants. A sodium flux is then added and roasting is undertaken to form a water-soluble sodium vanadate prior to leaching. The resulting liquor is then cleaned to remove silica and vanadium precipitated through addition of ammonium sulfate. This process produces ammonium metavanadate, which is roasted to oxidise it into vanadium pentoxide powder as saleable product.

9.4 CONCLUSIONS

- Mineral economics, specifically the interplay of minerals and markets, is a key aspect of the minerals industry – and forms an additional commercial consideration in addition to the technical aspects of project and mine management
- there are consistent forces at work across mineral markets that impact upon both supply and demand
- no two mineral markets are identical – and individual mineral markets change their dynamics over time in response to supply, demand and investor activities.

The best practice mine manager will seek out and monitor developments in relevant mineral markets. They say that a week is a long time in politics – it can be a long time in mineral markets too.

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Useful links

Base Metals: <http://www.basemetals.com>

Commodity Research Unit: <http://www.crugroup.com>

Iluka Resources: <http://www.iluka.com>

ITRI: <http://www.itri.co.uk>

Jinchuan Group Co Ltd (JNMC): <http://www.jnmc.com>

Johnson Matthey: <http://www.matthey.com>

Johnson Matthey, price charts: <http://www.platinum.matthey.com/pgm-prices/price-charts/>

Kitco: <http://www.kitco.com>

London Metal Exchange (LME), minor metals: <http://www.lme.com/minormetals>

London Metal Exchange (LME), molybdenum: http://www.lme.com/minormetals/Latest_molybdenum_prices.asp

Lynas Corporation Ltd: <http://www.lynascorp.com>

Metal Pages, metal prices: <http://www.metal-pages.com/metalprices/>

Antimony: <http://www.metal-pages.com/metalprices/antimony/>

Cerium metal and oxide: <http://www.metal-pages.com/metalprices/cerium/>

Chromium: <http://www.metal-pages.com/metalprices/chromium/>

Cobalt: <http://www.metal-pages.com/metalprices/cobalt/>

Dysprosium metal and oxide: <http://www.metal-pages.com/metalprices/dysprosium/>

Europium metal and oxide: <http://www.metal-pages.com/metalprices/europium/>

Ferrochrome: <http://www.metal-pages.com/metalprices/ferrochrome/>

Ferroniobium: <http://www.metal-pages.com/metalprices/ferroniobium/>

Ferrovandium: <http://www.metal-pages.com/metalprices/ferrovandium/>

Gadolinium and oxide: <http://www.metal-pages.com/metalprices/gadolinium/>

Lanthanum metal and oxide: <http://www.metal-pages.com/metalprices/lanthanum/>

Manganese: <http://www.metal-pages.com/metalprices/manganese/>

Molybdenum: <http://www.metal-pages.com/metalprices/molybdenum/>

Neodymium metal and oxide: <http://www.metal-pages.com/metalprices/neodymium/>

Praseodymium metal and oxide: <http://www.metal-pages.com/metalprices/praseodymium/>

Samarium metal and oxide: <http://www.metal-pages.com/metalprices/samarium/>

Tantalum: <http://www.metal-pages.com/metalprices/tantalum>

Terbium metal and oxide: <http://www.metal-pages.com/metalprices/terbium/>

Tungsten: <http://www.metal-pages.com/metalprices/tungsten/>

Vanadium: <http://www.metal-pages.com/metalprices/vanadium/>

Yttrium metal and oxide: <http://www.metal-pages.com/metalprices/yttrium/>

SPDR Gold Shares: <http://www.spdrgoldshares.com>

CHAPTER 10

STRATEGIC PLANNING

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INTRODUCTION

This chapter begins with an overview of the strategic planning process, including what should be covered in the scope, and what the key deliverables ought to be. This is covered by a discussion on strategic paradigms and work flow processes, followed by advice on strategic tools and their usage. Several key inputs to strategic planning then follow.

Industry analysis will assist a mine to understand the supply and demand implications for the future by understanding its market product's history. For example what the major forces in action have been, what the current situation is, and what the most likely future scenarios are. Competitor analysis is an extension of this and is particularly useful for local markets (for example bulk commodities), and where a significant amount of new production may be forecast with implications on the supply surplus/deficit.

Competitive advantage then examines how competitive a mine can be. Over the years mining operations have become far more cost effective with the advent of new technology. Effective mine managers and study leaders will have a deep appreciation for the implication of changing technologies and methods. All mines producing the same commodity can be compared on a cost curve, which provides insight into the longevity of operations in high relative cost positions.

Future price forecasting methods are discussed within the context of being a form of predicting the future. A range of potential price scenarios should be produced and contingency plans developed for high risk scenarios. Price forecasting builds on the industry analysis.

Finally an overview of risk management is provided. A mine manager will find that risk analysis is quite unique for each site, but many published guidelines will assist with comprehensive lists of items to review. Risk mitigation plans are often similarly unique and reliant on the level of risk assessed and the organisation's risk tolerance.

10.1 THE STRATEGIC PLANNING PROCESS

10.1.1 Strategic planning scope and deliverables

Strategic objectives define what the organisation aims to achieve (Chapter 1). Attainment of those objectives will be a consequence of a deliberate and rigorous planning and operational execution process. Strategic planning is still focused on the 'what' that needs to be done (or delivered by operations) with an appropriate level of thinking around 'how' (mining and process method, use of capital and human resources), the degree of which will be a function of the planning paradigm one is in at the time – project or operational.

Tactical plans that define the prioritised tasks, assigned responsibilities and accountabilities for execution, may still need to be developed as part of the strategic planning process. Their focus will generally be around major risk mitigation as opposed to delivering on incremental key value driver improvements embedded in budget plans, such as reducing truck queue times or equipment unmanned delays. An example of a major risk mitigation associated with an approved strategic plan might be for strategic planning staff to complete an options analysis for dealing with a short-term spike in stripping several years out that simply can't be mitigated by mine schedule optimisation.

Inclusive of this would be steps to determine availability, capability, indicative costs of potential outsourced service providers and the logistical, commercial and reputational practicality or fatal flaws of them completing the works.

For the purposes of this section, the strategic planning process is largely focused on the operational planning paradigm and covers major decision making for determining the rate and sequence of extraction over time and the expected value to be generated within defined business constraints using inputs that will change.

The strategic planning process is not carried out in isolation in so far as it must be a part of the greater management operating system as outlined in Chapter 1. While it typically may signify the start of a recurring planning cycle that will conclude with a budget plan, strategic planning will continue year round as new information becomes available and decisions need to be made.

The central deliverable of the strategic planning process, usually a primary accountability of the mine manager, is a physical mine plan typically of annual increments (or larger) comprising material movement and product content(s), inclusive of process schedule and economic model. The strategic mine plan will align with the organisation's strategic objectives and mission, honour defined constraints and use inputs with clearly defined expectation of eventuality on volume, efficiency and price (cost) drivers. The strategic mine plan will enable the enumeration, derivation and characterisation of all functional strategic drivers. For example, quantities of carbon emissions will be calculated from volumes of diesel and fossil fuel generated electric energy consumed by the mining and processing operations. Knowing this, a functional strategy can be put in place by those accountable for environmental management and, in turn, this can be incorporated into a complete business strategic plan.

10.1.2 Strategic planning paradigms

The strategic planning process for a major project (Greenfield Resource, major capital expansion for example) will feel quite different from that of an existing operation yet both will inherently address most of the same issues. For the former, it is a journey of discovery of what can be done armed with a threshold level of mineral deposit information often within only broad external constraints. Some constraints may be negotiable with community and government, for example final waste dump height limits and some may be less controllable, such as the availability of capital and the cost of people.

In strategic planning for a major project, assuming a market exists that will largely remain unaffected by the addition of the mining organisation's intended production, the big decisions will comprise:

- Mining method and selectivity – what is best suited for the style of mineralisation, material characteristics and deposit setting or location (relative to natural ground level and existing social infrastructure)?
- Process method and flow sheet – is there a feasible method for extraction and generation of a saleable product? What are the trade-offs on yield versus cost and does more than one product option exist?
- Scale of operations – how sensitive is the projected return on investment to production scale 'process rate'? Is the defined resource large enough and suitably defined to sustain it and can the mine keep up?

These decisions are invariably linked (Figure 10.1.1) and strategic planning must characterise not only the global maxima but also the surrounding 'optimal surface' such

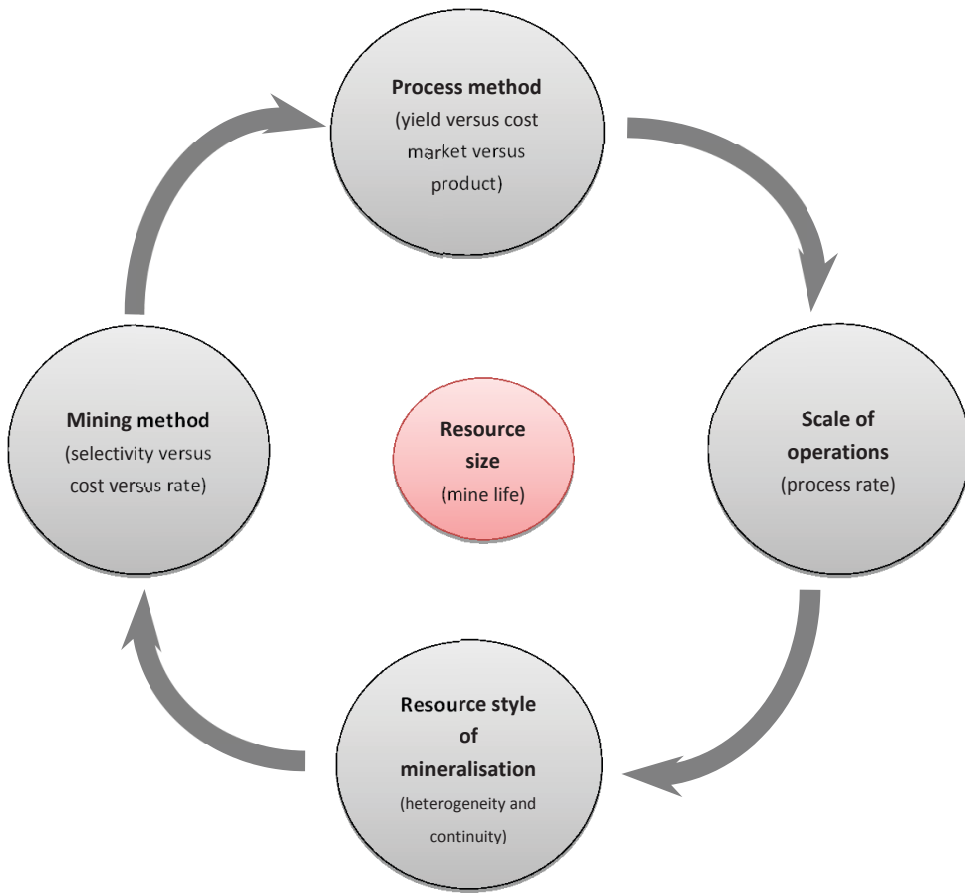


FIG 10.1.1 - Strategic operational design decisions.

that the right decisions can be made taking full account of the appetite for risk by the organisation. For example selecting one less of the largest semi-autogenous grinding (SAG) mills yet to be made might be less prudent than one more of the largest made to date and proven in the same application albeit for a lower total process rate. Knowing how sensitive the overall project value is to the de-risked lower process rate is paramount for strategic planning. The value potentially lost by adopting a lower investment and execution risk strategy of successive incremental expansions will come from a thorough understanding of the optimisation landscape leading to the global maxima.

No singular process or mine planning software tool exists to determine the optimal value combination with a single push of a button armed with what might appear all the necessary inputs. Additionally there is no one 'correct' answer for a given deposit. One can only make decisions based on available knowledge at the time, appetite for risk and access to and cost of capital. A common approach for projects is to tackle the optimisation for a range of key decisions called options or scenarios. For example, this approach might involve selecting a particular mining method, understanding the likely selectivity, mining intensity and cost profile that fits with the style of mineralisation, and then optimising the operational design for maximisation of net present value and return on investment. This can either be done heuristically or for more sophisticated tools allowing it to purchase processing capacity or 'scale' automatically. Tractability can become an issue for many commercially

available mine optimisation tools, so careful consideration of what is material, particularly with input data structure, is essential. Schaap (1986) illustrates the fundamental numerical relationships between these decisions in arriving at an optimal scale of operations for maximising the discounted present value to investment ratio for a large disseminated style deposit. Without too much imagination one can see that these numerical relationships can apply to other deposit types and settings (including underground). This approach is quick and simple and indicates the potential value based on using grade tonnage curves, fixed and variable capital and operating cost models. Schaap solves combining these models for the maximum discounted present value by also applying Lane's theory (Lane, 1988) for cut-off optimisation. By using grade tonnage curves (albeit informed or not for the envisaged mining method selectivity) it still assumes perfect or free selection of the deposit. The point being if the value does not look attractive under these simplifying assumptions it will not improve no matter how detailed a resource block model is used. More on the methodology for arriving at or re-testing strategic operational decisions is discussed further on in this section.

For an existing operation these decisions may not need to be made as part of a discovery planning process. However, they should constantly be revisited based on current information on costs, metallurgical performance, mineral deposit knowledge, a changing external environment and product price. On the other hand for larger mining organisations with expansive resources and a large land holding, significant project type decisions may be routinely embedded within an established operation's planning cycle that starts with strategic planning and ends with a high confidence budget business plan. For those that do not, the strategic planning process will centre on updating the plan based on changing circumstances from one planning cycle to the next and the re-establishment of the expected value of the organisation.

10.1.3 Strategic planning process workflows

Figure 10.1.2 illustrates a generic mine plan do check act (PDCA) cycle that starts with strategic planning leading into business plan generation inclusive of tactical plans and ultimately arriving at a budget. A snapshot of the generic PDCA cycle area of interest is captured in Figure 10.1.2.

FIG 10.1.2 - Strategic planning high-level workflow (refer to Figure 1.1.4 – Generic mine plan-do-check-act (PDCA) cycle).

An expansion of this workflow for an existing mining organisation could reasonably look like that illustrated by Figure 10.1.3. For the purposes of this chapter, it is assumed that the strategic planning processes contained with projects, mergers and acquisitions is beyond the scope of the operational mine manager.

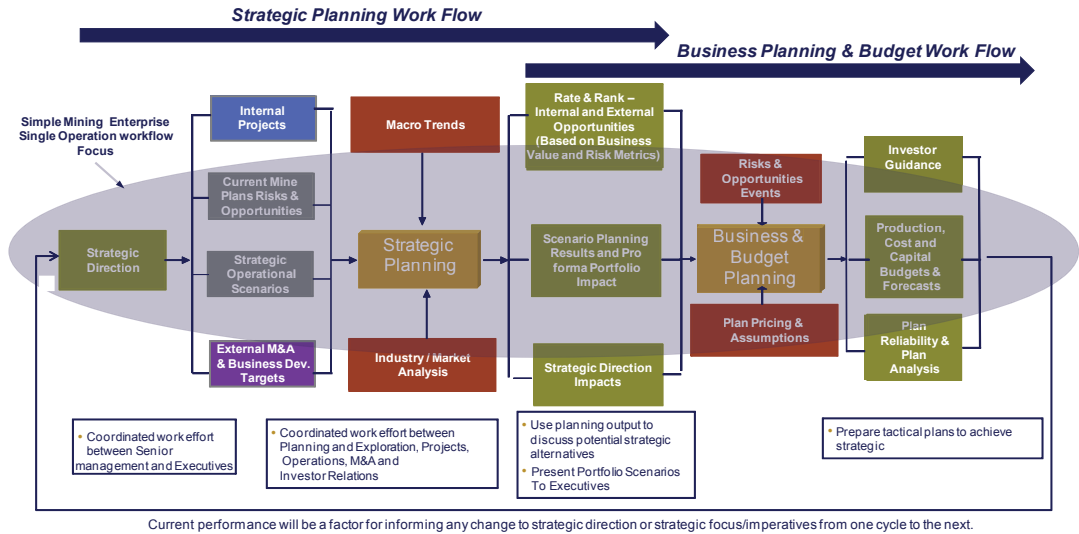


FIG 10.1.3 - Strategic planning workflow.

STRATEGIC PLANNING PROCESS THEMES

The split between strategic and business planning and budgeting regimes needs to be understood and tailored to the mining organisation. In Figure 10.1.3 the workflow is intended, once armed with strategic direction, to cast the net wide to gather options on what can be done, in essence gathering a ‘full field of view’, and then filtering these ahead of a more detailed life-of-mine business planning process so as to avoid detailed work on non-material options. The strategic planning process is aimed as much to eliminate poor options and ensure limited human resources work on detailing the best option(s).

Strategic planning effectiveness will be increased by adhering to the following theme:

- **Full field of view** – create this for all material options and not be artificially constrained. Don’t confuse being strategically thorough with being irrelevantly detailed. For example, using only Reserves and even Resources and not other potential mineralisation classes may create a poor view of the growth potential, or of increased economies of scale and the associated benefits. Constraining this view could contribute to decision-makers cutting drilling, with tenements not being tested to the limits of mineralisation and full maturity, result in ‘walking away’ from value. This is most important when mineral prices are rising rapidly and lead time to bring on new production is multi-year in execution. Drilling and planning only ‘within the money’ defined by rolling average metal prices may not reveal anything about the potential for future expansion.
- **Avoid prefiltering** – mineral strategic planners must not be allowed to prefilter based on their preconceptions of the future economic climate or of the decisions makers’ appetite for risk – this will curtail fully understanding the unconstrained ‘size of the prize’. Out of the money today can easily be in the money tomorrow with rising mineral prices.

The converse holds true so understanding what the plan will be in this instance is equally important and frequently undertaken as something of a surprise.

- Rapid and nimble – the strategic planning process should be rapid as well as thorough and not over work details.
- Use fit for purpose tools – apply tools and methodologies designed for strategic mineral planning that generate globally optimal solutions. Avoid backward application of detailed task or activity orientated schedule or optimisation tools that are myopic and not global in solution. For example the summed value of 20 one-year optimisations may not be the same (likely to be less) as one 20-year optimisation.
- Keep it real – the only sure thing with generating a strategic plan is the modelled outcomes and key performance measures will not be precisely correct. Executives and other important stakeholders such as shareholders, however, have a reasonable expectation that they fall within a range assuming all the things that can be controlled are controlled and for those that can't an option exists for dealing with it or a new plan will be generated. Consequently it is important to ensure input assumptions at the operational level are real and achievable or clearly identified as stretch goals and the strategic plan characterised and communicated accordingly. To this end paying attention to the more tactical trends from operation reviews using tools as outlined in Figure 10.1.2, such as value stream mapping (VSM) and value driver trees (VDT). For example, nobody benefits from having a strategic plan developed where truck operating hours (a primary driver of value) greatly exceed what has been achieved for the past few years in operation with no tactical plan defined to achieve the higher limit. Something like this can ultimately undermine confidence in the entire strategic plan.

PLANNING CYCLE AND CALENDAR

Figure 10.1.4 illustrates a generic annual planning cycle with realistic time allocations for each planning stage starting with setting strategic guidance in month 1 and 2 and culminating with presentation to board/owners and approval in month 12.

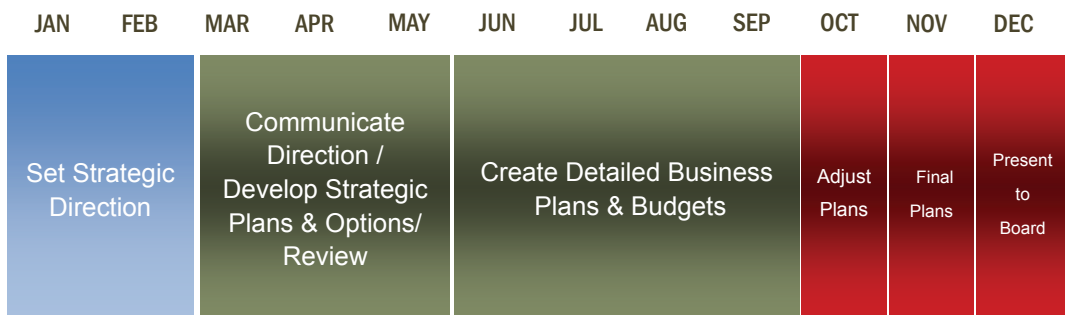


FIG 10.1.4 - Generic planning cycle – calendar.

There may not need to be a new strategic plan developed every year that examines all the scenarios in full covering projects; existing business plan risks and opportunities, strategic operating scenarios and merger and acquisition opportunities. Some organisations may only undertake this every two or three years subject to new material information such as significant resource extensions being available. That does not mean the existing business plan and mine plan does not need to be checked against changes in external risks and opportunities as well as any new strategic imperatives such as focusing on maximisation of cash generation in the near term while still maintaining 'optionality' to grow at a later date.

It is not unusual for business planning to include both a budget plan that covers the next year or two of operation and also an intermediate length plan (from three to five years is not uncommon) that allows for better planning around execution of approved capital projects that will come on stream within the life-of-mine business plan. Additionally it might make sense to have two 'life-of-mine' plans – one that optimises the operations without any major capital projects and another that optimises with the inclusion of major capital projects. At the very least, knowing what the difference in terms of organisation value and expected cash flows would be valuable (life-of-mine plans and budgets are covered in Chapter 7.3).

In summary, the more systematic and predictable the planning cycle is, the easier it will be to schedule limited resources who will, in nearly all cases (for example, planners, technicians and operators) have other activities to undertake during the year. The frequency of strategic plan updates will be a function of the options available, and the materiality of changes in the internal and external operating environment. Nearly all mines will update a basic life-of-mine plan each year even if they do not revise or change strategy.

10.1.4 Strategic planning process methods and formats

STRATEGIC DIRECTION

The larger the organisation the more poignant the strategic direction setting workflow will be each year. The information to assist with this may come as a direct consequence of some portfolio assessment from the previous planning cycle coupled with market and operating environment research undertaken at the executive or corporate level. The format for strategic direction can include some or all of the following in increasing detail:

- the overarching strategic direction cascades down from corporate strategy via
 - documented mission and objectives/definition of purpose/vision statement
 - stated corporate or business unit level key strategic objectives
 - policy documents, eg sustainable development
 - business unit strategic direction statement
- a letter or memo from the executive responsible for setting strategic direction including but not limited to
 - context on the state of the nation following the conclusion of the previous planning cycles including actual versus planned performance, external environment changes and rising risks
 - priorities to focus on such as cost minimisation, capital efficiency, maximisation of short-term cash flow, specific safety targets, global initiatives, recruitment levels
 - a schedule confirming deliverable dates for key reviews and submissions
- corporate functional guidance including but not limited to
 - price protocols for different scenarios
 - economic parameters (discount, cost of capital, escalation)
 - specific options or scenarios to be modelled that may include several mine plan options corresponding to different objective functions (growth, cost, production, value)
 - weightings for any ranking tools, eg value and risk category weights
 - limitations on class of mineralisation to be included
 - drilling and exploration expenditure scenarios
 - inclusion of closure costs

- updates to any standing guidelines on
 - mine design methodology
 - Reserve and Resource estimates
 - capital project estimation
 - closure estimates.

INITIATING STRATEGIC OPTIONS

There is no one size fits all method of developing strategic options; however, the more successful methods usually involve a developed tool or methodology that brings together the individual facets of the organisation to enable brain storming and consensus.

Many companies will already have defined methodologies that are used across the organisation. The advice in this section relates to mine managers who do not consider they have adequate strategic planning systems in place. While strategic options can be studied from text books, formal study and information available on the internet, a mine manager may find it more effective to bring in an impartial expert (internal or external) to assist with honouring the process and facilitation.

Methods used may include opportunity-brainstorming workshops supported by background studies such as; marketing and product strategy, process and mining methods, etc. Characterisation of brainstormed options aligned to strategic themes can be important if more than one strategic scenario is to be generated and presented. A project management and working group approach is not uncommon to deliver the strategic plan. Usually this working group will comprise dedicated strategic planning resources with others called upon to provide subject matter expert input depending on the nature of the options. A project management approach will ensure the planning cycle starts according to schedule with clearly defined terms of reference.

ASSESSING AND PRESENTING OPTIONS

Early communication of options and access to data requires good governance and trust. A fit-for-purpose strategic plan will be clear, simple and a reflection on the quality of work underlying the output.

For combining and organising initial options, strategic decisions and principle uncertainties, use of strategy tables and probability-weighted decision trees is often favoured. For example, an aggressive growth strategic scenario or theme may include decisions to expand infrastructure (or not) combined with high, medium or low certainty on Resources and price protocols. Other decisions may be included on applied technology.

One of the more useful subjective tools for characterising an option or scenario is a SWOT analysis (see Table 10.1.4), which can be used as an iterative tool. The strengths and weaknesses focus on the internal environment, whereas the opportunities and treats should describe the environment external to the mine. During formation there will often be some discussion over where any particular issue fits, as it may seem relevant to multiple

TABLE 10.1.4
Example of a 'strengths, weaknesses, opportunities, threats' analysis.

	Helpful to achieving objectives	Harmful to achieving objectives
Internal origins	Strengths	Weaknesses
External origins	Opportunities	Threats

categories. When initially formulating the options, decisions, uncertainties and issues or risks, good brainstorming will ensure items can be recorded in the multiple categories and then better defined as the process develops. For example, ultimately strategy will want to chart a course only through strategic decisions and will aim to avoid inclusion of tactical decisions. An example of a strategic decision might be the mode of haulage system, while the tactical decision might be the means by which the haulage system is powered, operated or controlled and the unit capacity of the system. The strategic planning would then concentrate on estimation and financial enumeration of those prioritised strategic scenarios or themes. This may also encompass evaluating how to turn weaknesses into strengths, threats into opportunities and to evaluate the risk of loss of strengths and opportunities.

For scenario modelling that requires a strategic mine plan to be generated, using such tools as presented in Figure 10.1.5 for open pit operations is a useful start. Finally, once all strategic scenarios are gathered and enumerated individually for production and value, additional analysis methods may be required to define priority or pecking order and the consolidated impacts (particularly if dealing with more than one operating mine):

- portfolio and balance sheet modelling
- risk assessment of overall value versus risk of investment
- rank and rate strategic fit type models for projects, eg a matrix/graph of strategic fit versus risk
- matrix/graph of ease of implementation ('do-ability') versus value.

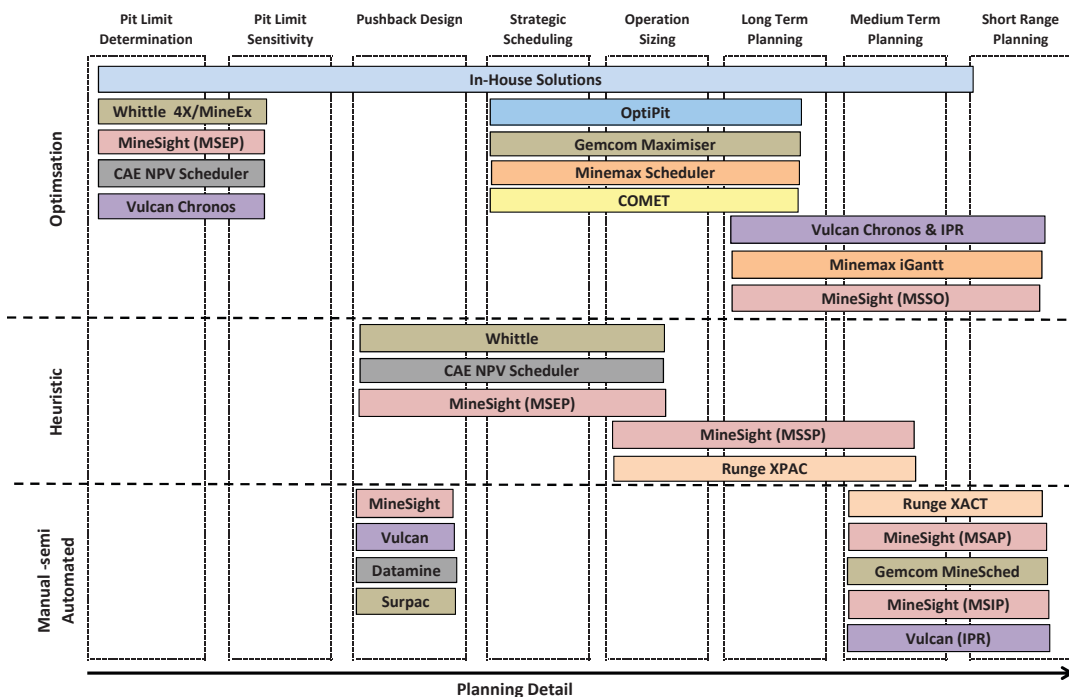


FIG 10.1.5 - Open pit mine planning software tools by planning function and regime.

The overall summary of the mine's strategy may be presented in a number of formats (usually more than one) including a SWOT analysis, with a gap analysis being highly recommended as a good overall summary to show gaps between strategic goals and current positioning, each with strategic initiatives to close the identified gaps.

10.1.5 Key strategic mine planning decisions

New mines should have a strategic plan from the feasibility study process (see Chapter 6.2); older mines without a strategic plan will need to develop one. Whether developing from scratch or reviewing a previous plan, the following items and key decisions may be appropriate:

- Underground mining method: is it still appropriate, are there possible improvements?
 - Important considerations include transport system – how to extend range (depth) and capacity; maximisation of Resource recovery: do economies of scale for the prevailing operating environment and market conditions warrant examination of engineered backfill or even open pit of remanent and lower grade zones?
- Production rate (final product): what is the potential to increase and what economy of scale could be achieved?
 - Important considerations include what is the cost and feasibility of associated infrastructure in residue storage facilitates, waste dumps; logistics (camps, transport of people, materials and product); incremental expansions of current production facility or a new one closer to mining operation.
- Development sequence: how sensitive is the intra or inter-pit development sequence to input assumptions?
 - Important considerations will include product quality specifications and constraints; availability of in-pit blending versus cost and practicality of ex-pit blending; opening (and closing) costs associated with new mining areas; availability and sharing of associated infrastructure.
- Mining rate: can the overall production rate be supported, has scenario modelling into the necessary timing of cut-backs and new mining areas required to support various higher production rates been completed?
 - Important open pit considerations include bench turnover or sink rates (benches per year); mining intensity (productivity per area of bench and total pit); ground condition (eg water, stability) on the former; practical (resource levelled) versus theoretical rates (spiky generated by optimisation software); and potential haulage congestion limits (for truck shovel operations).
 - Important underground considerations for the applied method include rock mass characterisation and stability; groundwater; tonnes per vertical metre; development rates; available ventilation.
- Pit limits: are there any changing issues such as blasting near towns? Or hard limits such as lease boundaries?
 - Important considerations include lead times for permitting and social licence endorsement.
- Selectivity and equipment selection: are scale and/or methods limited or enabled by current equipment of potential replacement? How is new equipment best sourced (contracted, leased, owned)?
 - Important considerations include: is the continuity and style of mineralisation changing such that it warrants reconsideration; is the mining equipment matched to any developing mine to mill tactical optimisation efforts?
- Cut-off and stockpiling: future opportunities for low-grade material to be treated, processing the highest grade feed early to minimise payback.
 - Important considerations will include cost and practicality of housing long-term stockpiles and degradation of ore quality over time and with exposure to atmospheric conditions.

The following examines some of the considerations surrounding one of the more obvious strategic mine planning decisions in developing an orebody, either as an open pit or underground mine.

UNDERGROUND VERSUS OPEN PIT

Underground mines can naturally develop through time below existing open pit mines or can start up based on their deep setting, or as a consequence of the deposit proximity relative to critical surface infrastructure. Underground mines can have less impact on the environment and adjacent communities. Consequently they may result in the only feasible options. Notwithstanding these considerations and assuming the geotechnical setting does not prohibit one or other mining approach, the point at which it makes more sense to mine as an open pit or underground will be an economic one. Specifically the evaluation will trade off volume of waste mined versus the unit cost of mining (in turn a function of the method and mining rate) such that total mining cost $[\$] = (\text{waste} + \text{ore}) [t] \times \text{unit mining cost } [\$ / t]$ (see Figure refer 10.1.6). As all of what is mined as production is milled from an underground, it effectively forces mining to be more selective. In other words the mill breakeven cut-off must include the full production mining cost. Compare this to an open pit where the mill break-even cut-off must only consider the difference in waste and product mining cost because the waste has to be removed to the surface anyway. Usually this is a small incremental number. For underground mines the mining cost is significantly higher than for open pits by as much as one or even two orders of magnitude and therefore managers are forced to be more selective (higher cut-off grade) and/or only develop higher grade deposits generally from underground. Not only is underground mining inherently less productive than open pit mining, the more selective one has to be the more compounding the problem. One might argue that block caving techniques are non-selective, low cost and high in production. This can be true but is more relative to other underground mining methods. Block caving still targets only those parts of the orebody for removal that are intended to be processed. Production rates are increasing and will continue to providing the setting is right. It is also not uncommon for underground mines to have increased reserve uncertainty/volatility and modifying factors combine to derive only Probable Ore Reserves from Measured Mineral Resources until the mine has proven its performance.

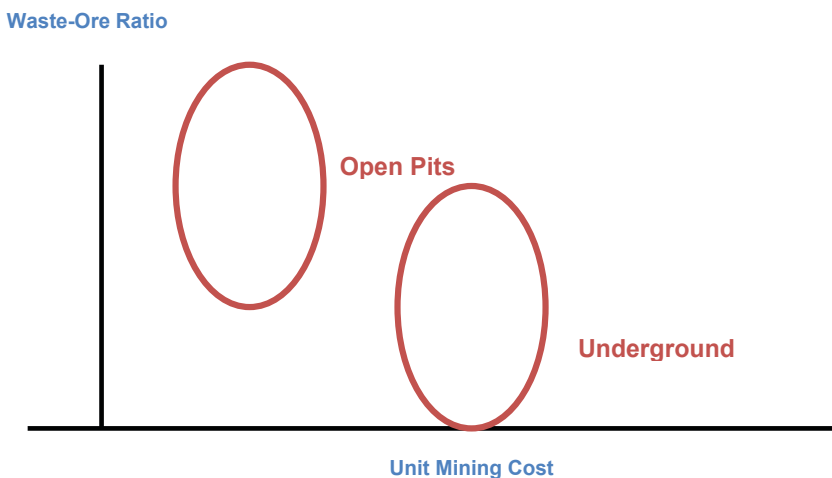


FIG 10.1.6 - Open pit versus underground mining cost relativity.

Different development approaches are driven by the specific challenges a project faces. Often process plant piloting is required early to assess risk and uncertainty. Where pilot plants are common for addressing uncertainty in metallurgy, test mining for underground is also common and recommended to address uncertainty in mining method, particularly in lower tonnage, more variable higher grade orebodies; starter pits will provide further insight into how final pit walls may behave. With lower mining rates and consequently production rates compared to open pit operations, capital infrastructure may prove too costly or render a Resource uneconomic to develop, particularly in remote and/or challenging locations with extreme climatic conditions.

10.2 INDUSTRY AND COMPETITOR ANALYSIS

A fundamental understanding of the future state of the industry, competitor intentions and capabilities are key building blocks for understanding future strategic direction and revenue risks. This section explains an effective process in analysing the supply and demand sides of a minerals market, and explains why understanding this is fundamental to one of the key business risks: potential future pricing effects on the revenue stream. This section is integral to price forecasting and lays the foundations for section 10.4 Sales and Price Prediction.

10.2.1 Why industry analysis is important to mine managers

KNOWING THE MARKET IS AS IMPORTANT AS KNOWING THE MINE

Revenue is the most important of the four cash flows of the organisation. Over the life-of-the-mine it must pay for the other three cash flows of capital costs, operating costs and taxes, and additionally provide a surplus to justify the investment.

Revenue typically is the product of recovered grade, throughput and price and so is derived directly from the mine's 'two bookends' of value:

1. the resources in the ground (including grade and throughput)
2. the customers for its products (including volume and price).

The activities of planning, constructing and operating the mine with their capital costs, operating costs and taxes, work between these two bookends by extracting the resources from the ground and delivering products to the mine's customers. For an organisation to be run and planned properly, knowing the global market is as important as knowing the mine.

INDUSTRY ANALYSIS IS ABSOLUTELY FUNDAMENTAL TO MANAGING A MINE

For mine managers and study leaders, the price forecast is one the most important inputs for managing the organisation. It is used frequently and widely across the organisation by geologists, mining engineers, metallurgists and accountants to manage, plan, optimise and reinvest in the organisation. A major change in price forecast might cause a major reshaping of the organisation.

Typically the price forecast is provided by marketing experts and then approved/adjusted by the most senior level of management and the board. The marketing specialists usually derive their price and volume forecasts from an industry analysis.

Thus in most companies an industry analysis is the source of one of the most vital of inputs for everyday management and long-term planning of the mine. Clearly the better the quality of the market research and interpretation, the more likely the mine is to be steering in the right direction.

GOOD PRICE FORECASTING IS VITAL FOR GOOD MINE MANAGEMENT

Any mine manager relying on a single-line forecast of price out for many years is being naïve, and misunderstanding the purpose of industry analysis. Instead the mine manager needs to work closely with marketing specialists to understand the various price scenarios the mine might face into the distant future. It would then be essential that the mine management team work through each of these price scenarios and so have plans of how the mine can adapt to exploit high prices and survive low prices. By contrast, a mine manager who focuses on one single-line price forecast is likely to point the mine in a wrong direction thereby making it inflexible and slow to respond to inevitable market changes.

MINING COMPANIES TEND TO BE TOO CONSERVATIVE

The end result of inaccurate price forecasting includes being both too optimistic (forecasting too high) as well as too pessimistic (forecasting too low). The results of over-optimistic price forecasting is lower than expected revenue, with financial disaster resulting all too often. As a result, most company boards and management tend to be cautious and conservative when forecasting price and prefer to err on the low side, which is often regarded as being prudent. However, erring too far on the cautious side will also lead to underperformance by undervaluing the Mineral Resources and Ore Reserves, mine planning incorrectly, undervaluing external opportunities, foregoing joint ventures, and underbidding on acquisitions. During the extended commodity boom brought by growth in China, many major and junior companies forfeited vast amounts of value by being too conservative and missing or delaying attractive opportunities.

In the mining industry there also seems to be a tendency to be cautious and conservative when forecasting price (or operating costs) for existing operations; it is easier to explain why the organisation has gone better than expected rather than explain why the mine has ‘underperformed’. Often the system of rewards favour those who exceed forecast, not recognising that a mine manager who exceeds target by a large margin is deficient in planning. Mine managers are rarely asked to explain why their planning was so conservative because they adopted a price forecast that was too low, or perhaps forecast too high an operating cost budget.

In contrast, many project managers will feel similar pressure to use forecasts that are too high to justify the continuation of a marginal project. There may be many reasons such as market expectations or the belief that the project can be improved with more work.

WHY MINE MANAGERS SHOULD NOT OVERSEE INDUSTRY ANALYSIS

It is unwise for mine managers (or study managers) to oversee the process of industry analysis and its consequent forecasting of price. This applies whether it is being undertaken by in-house marketing specialists or by an external, reputable organisation.

Experiences in the mining industry suggest that the reasons can be broadly grouped as:

- Inexperience – industry analysis is a specialised activity whether done in-house or be external consultancies where the experience of researchers is not always clear. Unless the mine manager has sound experience in the process and techniques, he/she will not understand all of issues involved, what relative value to place on vast amounts of information from other professionals, or how to value all of the uncertainties involved. Wise mine managers do not place professionals without the necessary skills or experience for a role in such a position of responsibility and should understand their own limitations. Mine managers should be aware of the level of competence required so they also do not delegate an analysis to employees who are ill-equipped for the task.

Often one will feel that something they know little about is far simpler than it is in reality. A wise mine manager will therefore understand that specialist skills are required for thorough analysis of the industry.

- Poor analysis – the mine manager should be aware of some of the indicators of a poor analysis. One classical symptom of a substandard industry analysis is huge amounts of reproduced detail and a long, professional looking report, yet this is not an indicator of the accuracy of conclusions. Organisations who have little ownership at the end use stage may provide volume without insight, and the manager should reference check past performance from potential consultants before engaging them. Another common criticism is that authors often follow the general industry view or worse, have sensed what the mine manager was hoping for and selectively researched to support this view.
- Subtle bias – mine managers are well aware of the sort of industry analysis that will match their personal ambitions, their key performance indicators and their team's objectives. It is very easy for them to subtly (usually subconsciously) influence the research and the price forecast if the mine manager appoints, assesses and rewards the market specialists. This is a perennial problem.
- Prejudice – study leaders (or mine managers) have been known to select analysts who would submit the sort of price forecast needed to progress the project (or the mine), and worse still, reject conflicting evidence. If the research appeared to be leading to a less than supportive forecast, the study leader has then pressured the market specialists to produce an industry analysis that fits their personal needs. The organisation was steered into the wrong course, but the study leaders retained their jobs and perhaps even received a bonus.

Unfortunately there is a long and sad history in the mining industry of poor industry analyses from these causes. As a result mines have been managed suboptimally, economic projects were not funded, uneconomic projects have been kept alive and new mines have been commissioned into a disastrous market. Mine managers should consider the reward systems within their companies to ensure study leaders and their teams are not conflicted by these reward systems (by way of bonuses or job security/promotion) for an industry analysis/price forecast that is inaccurate but useful in justifying a project.

Companies can lessen these adverse outcomes through good corporate governance – including a robust peer review process and by having an impartial senior manager with a sound knowledge of industry analysis oversee this vital activity. Other helpful strategies include commissioning more than one consultant in parallel and reviewing analysis against publically-listed research reports, which may provide a range of conclusions to assist with sensitivity analysis inputs.

MINE MANAGERS NEED TO EDUCATE THEMSELVES

Mine managers (and project leaders) should use the organisation's industry analysis to educate themselves about the global market; its history, the forces driving change, possible future scenarios and the full range of potential price outcomes. They should understand the mine's threats and opportunities. They should not be quarantined from the industry analysis but should actively follow progress, challenge processes and findings, and perhaps be actively involved so that upon its completion the conclusions and any forecasts are competent, objective and reach a consensus.

10.2.2 Industry analysis

THE PROCESS

The most productive way of getting inside an industry is to first research the two sides of its market: demand and supply. These are then brought together to form a view on whether the markets will be in surplus or deficit. Finally a focus on potential customers and competitors will provide the basis of a price forecast and a marketing plan. The overall process for mining is first outlined here and then explained in detail below.

- Analyse and forecast demand
 - analyse demand history, including the forces that have shaped that history
 - identify the key forces that will drive demand in the future, including strong and weak scenarios
 - synthesise demand into the future for a full range of possibilities – for example minimum, maximum, low, high and mid.
- Analyse and forecast supply
 - analyse supply history and especially the forces that shaped that history
 - identify key forces that will drive supply in the future, including their strong and weak scenarios
 - synthesise supply into the future for a full range of possibilities, for example; minimum, maximum, low, high and mid.
- Forecast global volumes and prices
 - mix and match supply forecast scenarios with demand forecast scenarios to generate estimates of evolving market surpluses and market deficiencies
 - forecast price and volume trends for a full range of possible industry scenarios such as minimum, maximum, low, high and mid.
- Generate a marketing plan for the mine
 - Focus on the mine's key customers and key competitors, including a SWOT analysis.
 - Generate a marketing plan that recognises the full range of possible scenarios. It should produce a base case to steer the mine and to develop a production plan. This plan should be capable of flexing toward minimum or toward maximum. 'Mid case' marketing plans very rarely eventuate, so the mine management has to be ready to adapt to whatever evolves globally.

Analyse and forecast demand

- Establish the history of global consumption back to 1900 or before if possible, but as a minimum back to the world's major economic growth, which began in the 1950s. This should provide a long enough base, as market histories dating back only 20 or 30 years can give misleading impressions ('new' metals and commodities will of course have shorter commercial histories). Selective analysis of a period of history to support a demand profile is not usually wise and has been used in the past to support preconceived demand profiles.
- Split this global history of demand into major natural categories.
- The prime set of categories should emphasise the underlying market and 'customers' needs' rather than 'end products'. Always view the market from the perspective of the customers and not from the perspective of the producers. As illustrations: 'starting

a vehicle' rather than 'lead batteries', 'structural integrity/longevity' rather than 'galvanising', or 'wealth storage' rather than 'gold bullion'. This encourages underlying technology and economic forces to be better recognised.

- Where transport costs are a major factor, such as with bulk minerals, the split should be repeated into natural categories by sorting according to geographic regions related to the cost of transport, where customers tend to purchase within the region.
- Where ownership or long-term commercial/political/religious relationships are significant a split should be performed.
- Analyse the histories and identify forces that have shaped demand in each category.
- Forecast how these forces may evolve in the future and any new forces that may be created by technology, global economics, substitution, production as by-products, new products, politics, etc.
- Generate strong, weak and mid-scenarios for each, recognising how these forces might interact.
- Understand how the key customers for the metal or mineral will evolve; which segments or geographic regions will grow and which will recede. Identify key customers who should flourish and those which may wither or exit.
- Synthesise future global demand for a full range of possibilities, for example minimum, maximum, then low, high and finally mid.

It is important when creating scenarios for mid, high and low, maximum and minimum, not to start from the mid-case and work outward. This normally invokes unconscious prejudice and overconfidence to yield narrow ranges. Instead start from the extremes of how bad this could really get if the world collapses or how good if it booms, and then work inwards to highs and lows, and finally to conclude the mid-point.

ANALYSE AND FORECAST SUPPLY

Continue the above process for the supply side:

- Split the global history of supply into major natural categories
 - Begin with underlying customer needs rather than by end-product types.
 - Second, split by geographic region if transport costs are important, or by quality.
 - Third, split by ownership or long-term commercial/political/religious relationships if these are significant. Some metal and minerals industries are vertically integrated to a high degree therefore most customers are likely to be purchasing most of their metal or mineral requirements from a related party.
 - Analyse their histories and identify the mineral deposits and the forces that shaped global supply.
 - Global industry cost curves can be extremely valuable in deciding the future of each mine and project. Create economic models of key global and regional mines. This provides a sound basis for comparing and later deciding which mines may expand and which may exit.
 - Forecast how these mineral deposits and these forces may evolve in the future, including the exhaustion or expansion of existing mines and the commissioning of new mines, and the potential for new discoveries in emerging mineral districts. Generate strong, weak and mid scenarios for each.
 - Synthesise global supply into the future for a full range of possibilities – for example minimum, maximum, then low, high and finally mid.

Forecast global volumes and prices

- Mix and match supply with demand across a full range of scenarios to generate sets of surplus or deficiency. Forecast prices for maximum, minimum, high, low and mid. This is the most difficult step and therefore the most controversial. There are several techniques for forecasting prices that can be explained by experienced market specialists and by research on the internet.
- For the mine manager (and study leader) this gives the direction of where the market is likely to head into the future. Probably equally important is that it provides a measure of how bad or good things may get. While a mine needs to be managed and planned to be at optimum on the mid-scenario, it must also have contingency plans to be able to adapt to markets turning sour or booming.

Generate a marketing plan for the mine

Begin with an understanding on the strengths and weaknesses of the mine's products or potential products, for new orebodies this should include some direct approaches to potential customers with a full specification sheet of the mine's proposed product (including credit and penalty elements):

- Focus on the mine's key customers (existing and potential). Look at the market from their perspectives to understand their particular needs and why they would purchase from the mine. Ask how will the mine's product quality, volume, form, logistics, timings, etc need to change and evolve to capture or retain their custom.
- Identify the key customers that have a competitive advantage that will enable them to survive in business. Identify key customers at risk of market evolution and who may not survive. It is dangerous developing a marketing plan that relies on vulnerable customers.
- Focus on key competitor mines (existing and potential). Understand their strengths and weaknesses. Create high-level economic models of their businesses.
- Using all the knowledge from the above industry analysis to conduct a SWOT analysis of the mine.
- Generate a marketing plan, with a full range of possible scenarios, for the mine to steer its business and most importantly, develop a flexible production plan.
- Include an assessment of any price premium or price discount that would be brought by the mine's product quality and geographic location (compute its 'value-in-use' when consumed by the customer).
- 'Mid-case' marketing plans very rarely eventuate, so the mine manager has to create a plan that is ready to adapt to evolution in the global industry.

Sources of data

As with price forecasting the best sources of information include:

- Seasoned marketing professionals in that metal/mineral. In-house experts should be able to provide historical data, explanations of the market's evolution and driving forces in the future.
- Internet searches: common minerals and metals have very long histories of sales available from a variety of web sites. The World Bank Commodity Price Data (Pink Sheet) lists in Excel, monthly and annual prices in US dollars from 1960 for energy, raw materials, agriculture and metals and minerals. The US Geological Survey, producer organisations, customer organisations and a few company web sites are other sources.

- Commercial market research organisations of course will research history and may directly contact customers and competitors. The processes and motivations of the market research organisation and its individuals need to be understood and this is discussed below.

MINE MANAGER'S ROLE

Mine managers need to have a broad overview of the market and to think divergently. They should not limit the mine management's thinking and planning to the mid-range case but demand that planning be flexible and adaptable.

Mine managers should never blindly follow convention and industry practices, and should be distrustful of any mathematical process that derives a price forecast (black box solutions) without a logical explanation.

Mine managers should seek out views on the future of competitor mines, especially new projects, and balance this with the risk of uncertainty in future events. Over time, experienced professionals may develop subconscious (or overt) biases and outdated views, which do not readily adapt to the changing world. Managers therefore have to place a weighting on any subjective view/opinion used in their analysis of the industry.

A feature of human nature known as 'group think' can develop in mine management teams where insufficient outside input is used. This can result in failure to appreciate other perspectives, including the customers', with a resulting optimistic view of market evolution that may suit the mine, and an accompanying set of logic as to why customers and competitors will comply with this view. By contrast, if those same people were managing a customer or a competitor-mine they would probably adopt a contrary view. This is best overcome with outside/peer review of marketing plans, and direct contact with customers.

Similarly it is common to underestimate the resilience of companies in a market downturn, and to predict a closing of marginal mines. Some troubled mines defy the odds and survive using a variety of devices including marginal analysis, and postponed maintenance.

A mine management team performing industry and competitor analyses will be more effective with at least one free thinker to adopt the role of the customer and competitor.

10.2.3 Commercial industry analysis organisations

The industry analysis can be done by a mix of in-house and external organisations. Larger companies are more able to justify in-house staffing augmented by external research, whereas smaller companies tend to hire external market specialists¹. Some small market research companies have proven very effective in focusing on special metals or special commodities. Other small research organisations specialise on a narrow product segment of the market or on a geographic region.

Mine managers (and study leaders) should not automatically defer to the expertise of a market specialist and passively accept their conclusions. There is a history of research organisations getting markets and price forecasts very wrong: including major, respected research companies.

External research organisations are aware that they are more likely to get further work if the market is made to appear attractive, at least in a special niche, and if price forecasts are higher rather than lower, or research that concludes that further work is often required. These are risks of which the mine manager must be conscious.

1. Much of the material presented in the previous chapter falls into this category.

Large market research organisations should be able to develop rigorous research procedures and cultivate a wide network of industry contacts. While there are good reasons why they should produce high quality industry analysis, being well established in an industry does not automatically mean high performance due to factors such as:

- staff turnover so the expert of past years may no longer be undertaking the analysis
- in poor markets there will always be the temptation to use cheaper junior staff, and in overheated markets, the experts with experience are few and far between, again resulting in junior staff performing much of the analysis
- the excessive use of junior staff may lead to short-cutting by updating a previous report rather than reviewing from first principles
- individual skills, experiences, perspectives and biases can influence the conclusions
- research thoroughness can affect the outcomes, eg desktop research on the internet instead of site visits.

Therefore the mine manager should be aware of the profile of the market researcher and methods used (good reports will state this up front).

Some small market research companies have proven very effective in focussing on special metals or special commodities. Other small research organisations specialise on a narrow product segment of the market or on a geographic region.

As with any research, the output is only as good as the individuals undertaking the market study, their experience, effort and motivations. Unfortunately in both big and small organisations some persons can become over-confident or have biases creep in and so the research becomes subjective.

Any industry analysis report, including those done very well, should not be passively accepted but perused and compared with other sources of the same information. It should be treated as one set of opinions made by a party that may have a mix of motives. If done well it should provide a base for the organisation to understand demand/supply, the key players in the market and the forces that will be driving change in the market. It could be used as a starting point for the organisation to develop its own conclusions.

Every organisation has to make its own conclusions and develop its own marketing plan, and a mine manager must accept shared responsibility for the forecasts used.

10.3 COMPETITIVE ADVANTAGE

Competitive advantage is an economics concept that in this context compares the relative advantage of certain aspects of competing mineral products. Competitive advantage plus the nature of the resource in the ground will decide how good a mine can become as a business.

Customers have underlying 'needs' to be satisfied; how they want satisfaction is their 'want'. There is a difference that is illustrated by the evolution of products in the mobile phone industry, and the rise and fall of the competing companies: customers 'need' communications capabilities, but may 'want' this in ever changing forms. In the minerals industry it is the properties of end use rather than the metal itself that satisfies needs, eg gold is a store of wealth; however, gold itself sitting in a vault has no other advantage.

When referencing the mineral product that customers have a need for, there often becomes an approximation to the economist's 'perfect market': where all products are

homogeneous (or able to be compared by means of sales formulae for quality and mineral/metal content), there is perfect knowledge (not possible but with the information age a much better approximation), and no customer or producer is large enough to influence the price (debatable with some mineral products). In this context a competitive advantage can have a number of sources, and exists whether the mine manager is in tune with this concept or not.

The position on the global cost curve (the supply curve of each mineral product) is usually the equalising comparison between mines. The cash cost of production incorporates all of the competitive factors to arrive at the position on the supply curve, and enables some competitive positioning conclusions to be drawn.

10.3.1 Demand and supply

DEMAND SIDE

A marketing text book on 'competitive advantage' is likely to focus entirely on how to change the offering of goods or services to best satisfy the customers' needs and wants. It would seek ways to differentiate what is being offered for sale to more fully capture customers, and so as to expand market share and profit margins. A text book would focus on the demand side of the market.

This introduces the concept of secondary minerals markets within the metals chain. Mine managers need to be aware of these in order to understand who their customers actually are. In the case of precious metals this is often a refinery, of which there are few. In the case of most base metals, it is often the custom smelting industry with few recent examples of mines and integrated smelters being built. The recent base metals smelter capacity increases in Asia (particularly China) have often resulted in a more competitive market for concentrates (particularly copper) than for the final refined metal that goes to traditional customers to produce the final end usage products.

For bulk products such as iron ore and coal, the end use customer is often the power consumer (thermal coal) or steel consumer (iron ore and coking coal). However, the mine's customers will not be the end user but rather the power station or steel smelter using the above examples. Product differentiation (quality) and transport factors in this context must be well understood by the mine manager.

For mines the ability to change the goods being offered in the market usually is quite restricted. Mine management should be fully aware of its customers' wants, but typically will be limited in making radical changes to its products. Two of the biggest differentiators – quality and location – will be largely predetermined:

- If the mine sells a mineral or concentrate then its quality is dominated by the character of the ore deposit that is in the ground. A copper mine can use sophisticated processing to upgrade the concentrate, and the presence of precious metals in the ore will be an advantage, while if high levels of iron and arsenic are present at atomic level then the product is likely to suffer. If cadmium was co-precipitated when the phosphate rock deposit was formed then it is likely to persist through to the final product and downgrade its attractiveness to fertiliser manufacturers. Argyle diamonds, on the other hand, was an exception in developing a new market segment for its previously unsalable 'champagne' coloured stones.
- If the mine sells a metal or refined chemical intermediate then its quality is probably determined by a long established international standard of purity and there is limited or

no room to differentiate. Final copper metal offered for sale is likely to be something like 99.99 per cent copper. Tungsten can be offered as ammonium paratungstate (APT) and nickel as a hydroxide.

- For minerals and metals, the mine's proximity to global customers – its geographic location – would have been decided eons ago in geological time. An energy coal deposit would suffer huge competitive disadvantage if it had formed in Central Australia. By contrast the Yampi iron ore deposits were extremely high grade and their shipping wharves were constructed just a few hundred metres away.

Thus the genesis of the ore deposit is likely to dominate the demand side of a mine's competitive advantage in the market place; its ability to differentiate and offer minerals/metals of special attraction in a superior geographic location.

Gold is the prime example of a global mining industry where the demand side of competitive advantage has no relevance. It is a standard product where geographic location is almost unimportant to customers.

SUPPLY SIDE

For mines there is arguably a second dimension to competitive advantage that may be omitted from textbooks: the supply side. For most mines the costs of mining and delivering products is the key measure of competitive advantage. But like the demand side, it too is dominated by the genesis of the orebody. It requires a systematic analysis of competitors within the industry, and is outlined below in the section on cost curves.

One of the largest supply side competitive advantages is the relative grade of a deposit, and value of the final product. In this context the saying 'grade is king' indicates that higher grade is a competitive advantage, as is purity of the saleable product, the ease of mining, the closeness of major infrastructure (power, water, transport, labour, service industries, or mining limitations such as ease of tailings storage) and the presence of other valuable elements (eg Co, Mo, Au and Ag as by-products). Combined, these describe the natural endowment of a mineral deposit.

A low-grade deposit will find the majority of cost per saleable unit (eg pounds of copper) to get its metal to the end use customer is in the actual mining, whereas a high metal content orebody will have a lower portion of mining costs per saleable unit. Bulk commodities will find that the majority of costs are in transport of the saleable product, and precious metals will largely be mine-site-based costs with only a tiny physical output transported to market.

Each mine will have unique characteristics that can add value to the customer and the mine manager must determine whether the cost of product enhancement is returned to the mine.

10.3.2 The mine manager's role

The mine management's role in 'competitive advantage' is important to the future of the organisation. It should work closely with the marketing section to:

- exploit whatever advantage it can offer to customers
- understand where the mine sits in the global industry.

The mine management team should see itself as part of a team that knows its customer and key competitors almost as well as it knows itself. Each global mineral and metal industry is forever evolving and changing, sometimes in unexpected ways, and mine management should make itself aware so it can steer the mine in the best direction.

IMPROVING THE MINE'S OFFERINGS

Firstly mine management needs to work closely with the marketing department to regularly interact with customers to focus on what they want, and how the mine can improve its offerings to be more competitive. It can be especially fruitful for the mine manager and the metallurgical leader to visit the customers' works and develop a working relationship. This can be a very positive way of differentiating the mine's products.

Mines cursed with what seems to be competitive disadvantages usually have to work the hardest to retain existing customers and win new customers. If product quality is inferior because of contaminants in the mineral concentrate, or if the mine is an expensive distance from customers then the organisation will suffer reduced income. Unless the global industry is very profitable, the mine is likely to operate at low margins. The mine management may be alert and creative, but find the cost of product innovation a burden.

At the other end of the spectrum, mines blessed with enormous, high-grade deposits may become strong negotiators in the market place, get premiums and schedule shipments to suit their own production. Their biggest risk is that they become complacent, even arrogant, and alienate customers, because one day the market may well reverse or an alternative supplier may come into the market.

Product quality

If a mine manager looks at his/her own industry as it was decades ago and compares it with today he/she is likely to see evolution of products. As technology improves, prime deposits exhaust, new deposits commission and the whole industry slowly innovates, so the competitive environment changes. Looking back over the decades will reveal the most successful and well-regarded professionals did not become entrenched in their own knowledge of the industry nor limited by their own experiences, but embraced change and new technologies. A key success factor for any long running mine (and indeed professional) is to actively seek out new and more efficient methods for their competitive advantage lest the operation begin to slide up the global cost curve. Product quality is typically increased gradually through constant focus on plant and mining operations, better knowledge of mineralogy, etc. Mine managers are therefore warned of the tendency with age to become entrenched in their own knowledge and limited by their own experiences and of the potential consequence of dismissing new perspectives and making superseded assertions about product quality and volumes.

The purchases of major industrial minerals and metals, like energy coal, coking coal, iron ore and copper, needed to meet demand in China and the developing world, have expanded so rapidly that the norms of decades ago have been left behind. In iron ore and coking coal, companies now successfully mine deposits previously considered technically and commercially unusable. They offer a new range of intermediate products to the global steelmaking market. This innovation in the market has been ushered in by the need for very large increases in volumes and the resulting need to develop better technology in steelmaking to use poorer quality feed. Some of the mines able to adapt and exploit these new products have triumphed.

Mine managers should relentlessly push their mining, metallurgical, logistics, sales and commercial experts for ways to become more competitive. Progress is likely to be slow but it is important that management teams persevere.

Geography

For bulk materials of relatively low value the geographic location of the mine will be important. Mines close to customers or close to deep water ports will have a major advantage. Saudi Arabia recently established several brand new, major mining industries with railways to new deep ports on its east coast because it could ship at low cost to India and Asia. Where geography is important the product offerings in the market might need to be adapted to match the particular needs of niche customers within the local region.

Commercial terms

For most global mining industries the product logistics and payment terms are likely to be well established. The cargo sizes, transport method, delivery schedule, price computation and payment terms have become almost standard for many minerals and metals for many decades. Nonetheless the mine manager should be encouraging ways for the organisation to differentiate its products and offer a more attractive commercial package. A mine trying to break into a market may need to offer some special benefits², so an existing mine should consider if breaking with convention would bring worthwhile returns.

Corporate and political relationships

For some mines a competitive advantage is a corporate or political relationship. Common ownership, political or social alliance, import tariffs and export penalties can mean purchases are directed to a particular mine. These markets are not always level and fair. Of course this competitive advantage is not natural and will last only as long as the relationship.

MONITORING THE INDUSTRY

As outlined above in 'Section 10.2 Industry and Competitor Analysis' and below in 'Section 10.4 Sales and Price Prediction' the mine manager should know the market as well as he/she knows the mine. The activities of analysing the industry and forecasting the price are described in those two sections.

Price forecasting is one of the most critical inputs for the management and planning of a mine and the mine manager should understand its derivation and the range of possibilities so they can steer the mine in the right direction. The mine plan should be flexible enough to adapt to market ups and downs, even as far as its forecast maximums and forecast minimums.

Mine managers should understand when capacity restraints will enable the mine to change cut-off grade with changing prices, and the degree to which long-term mine profitability can be affected by changes in cut-off grade. While orebodies tend to 'breathe' in and out with changes in commodity pricing, there is often a number of practical constraints in the operations that prevent the mine from taking full advantage. When prices rise, marginal revenue increases and the cut-off grade can be reduced. However, operations are typically constrained by a process step such that this lower-grade material will displace higher-grade material and that total potential profit may well be reduced under a cut-off grade reduction.

For mine management, understanding the global industry should rank along with managing the mine's operations, planning, accounting, environment, community and commerce. Analysing and monitoring the market is likely to be performed by the marketing department, but mine management should keep itself informed and help evaluate competitors' operations, costs and advantages.

2. Such as a new entrant to market discount, or 'entry fee'.

10.3.3 Global cost curve

A key output of industry analysis is the industry cost curve. It is a simple graph of columns where the width represents the output and the height represents the cost. Columns are sorted from the shortest on the left, to the tallest on the right and often described in quartiles with the lowest on the left.

Plotting an existing mine or a proposed mine on the industry cost curve is very illuminating as it gives the mine's comparative cost relative to all others. If expansion of the mine is proposed, the position before and after will be most revealing, with most new mines ideally aiming to be in the first or second quartile. Mines in the fourth (highest cost) quartile are the first to experience cost stress in downturns, and are typically low-margin mines in good times. This positioning exercise should be required as part of any mine assessment and any investment decision. It should rank with net present value (NPV) and internal rate of return (IRR) when important decisions are made.

Of course the position of a mine on the cost curve is largely determined by the nature of the orebody and its location. Low cost mines in the bottom half find it easier to justify investment and expansion, providing it does not significantly worsen its cost position in the industry. By contrast any project leader whose proposed mine slots near the top of the cost curve should have a serious challenge if the decision-makers are knowledgeable.

PRICE FORECASTING

Some marketing experts use the highest cost producers as a base for price forecasting. This pricing method is available from market professionals and on the internet.

MINE CLOSURES

In theory any mines with total costs above the market price for an extended period are supposed to close down. In practice many appear to defy gravity and keep operating because of hidden benefits such as employment, political pressure, environmental liabilities, closure and redundancy costs, face-saving and optimistic price forecasts. Mines will generally not reduce production if the marginal cost of production is lower than the marginal revenue, which is related to the market price.

THE DETAIL IS VERY IMPORTANT

While the concept is simple, the computations underlying a cost curve can be contentious, and might become misleading. Some costs should be included, some costs should be excluded – but others need clarification. Two broad sets of cost curves are in common use and another seems useful. They are:

1. cash costs (C1) – the most commonly used
2. full costs (C3) including depreciation, etc – of less interest to mine managers since they include past capital expenditures and future accounting charges
3. incremental costs – rarely produced but would be a useful guide to which producers can survive a market downturn and which are more likely to exit.

Only cash costs are outlined below.

CASH COSTS

The most useful cost curve is based on the average cash costs to operate the mine and deliver products to the customers' works. These include:

- Mine site operating costs including administration, supply and despatch, logistic costs, tailings dam and waste dump cash expenditures, community and environmental costs paid in cash.
- Operating maintenance, major replacements and ongoing capex to keep the mine operating, but not capex for growth.
- Local office and head office incremental cash costs incurred specifically in running that mine and which would disappear if the mine did not exist.
- Product delivery costs to the point-of-sale, including sales expenses, transport costs, warehousing, loading, unloading, port fees, insurance, direct marketing expenses.
- Payment terms, treatment charges, refining charges, penalties and other mechanisms where the price received for an intermediate product, such as a base metals concentrate, is based on the final metal price, such as zinc metal and copper metal, and these cash costs represent the portion of price going to the smelter.
- Premiums and by-product credits are deducted from the cash costs (as negative costs).
- There can be debate about whether a substantial 'by-product' should be considered in its own right as a stand-alone 'co-products' and if so, how to allocate costs. There seems to be no right and wrong. Instead the key is to understand how it impacts and be consistent.
- Some customers incur costs or benefits in consuming a feed material that are far greater than the penalties and premiums built into the pricing mechanism. High ash coking coal for example may cost the blast furnace \$30/t in energy and limestone but have a standard price penalty of only \$10/t. The cost curves should include this extra \$20 burden as 'value in use', so that the true position of the mineral in the market is assessed.
- Some cost curves omit government royalties, but include private ones. This seems irregular because government royalties are direct, unavoidable cash costs of getting the product to the customer.
- Indirect taxes incurred in the operating and ongoing capital expenditure should be included.
- There will be other expenses that are 'grey' and that could be reasoned either way. They should be included if they are necessarily paid to an external party to get the product to market.

Cash costs do not include:

- non-cash items such as depreciation, accounting reserves and closure provisions
- growth capital expenditure
- income tax, international withholding taxes
- management fees, which are not for specific services necessary for the mine to deliver product.

10.4 SALES AND PRICE PREDICTION

10.4.1 Grade and price are kings

'Nothing is more important to a mine or minerals operation than the recovered grade and the price!' Usually these two dominate the organisation, whether in operating phase or in study phase. Mathematically, over the life-of-the-mine, the tonnes × recovered grade × receivable price = revenue, and this has to be bigger than the capital costs + operating costs + taxes for the mine to be viable.

Recovered grade and price come from the ‘two bookends’ of value for any mine or project:

1. the ore in the ground
2. the market for its products.

These two largely determine the upper limits of how successful the organisation can be. Everything between – including mining, processing, logistics and costs will get the product to market and absorb part of this upper value.

Price forecasting is usually done in a foreign currency, typically the US\$, and therefore price predictions in local currencies must be paired with foreign exchange predictions. The two are linked and in many mining countries one partly offsets the other.

10.4.2 Mine managers should ‘get inside’ the price forecast

Too often mine managers and study leaders receive the price forecast from head office or marketing and passively accept it as ‘a given’ and as absolute. While they may be required to report based on that one number, they will be the ones leading the charge, should a different price environment emerge. Mine managers are strongly advised to understand the range of forecasts behind that one number.

By contrast, mine managers and study leaders almost certainly need to oversee a lot of effort in order to thoroughly understand their production plan. They will demand diligent studies of the resource, mining and metallurgical processes. These studies normally require a large amount of highly skilled intellectual activity and numerous scenarios to be tested. For important decisions the results will be independently reviewed by peers. All this is very necessary and should produce a high level of understanding and confidence in exactly what can be produced. Ironically one the most influential inputs to this process will be the price forecast (and associated exchange rate).

Mine managers and study leaders should have as much awareness of the derivation of price as they do the derivation of the production plan. Ideally they would participate, but at least have full knowledge of the price forecasting processes as they take place. They should apply the same intensity of awareness to the price forecast as they do to the technical and operational inputs. Knowing the quality of the organisation’s price forecast and its underlying uncertainties allows the managers to better oversee the work of their teams. Instead of mechanically inserting the set of price forecasts into the one final business plan, the team should re-engineer the business plan for each of the full range of possible market scenarios, and possibly beyond. The final business plan should have the flexibility to adapt to any price development as the market evolves. Using easy-to-follow economic models, the mine should be able to be steered from the present through good times and through bad times and back.

Once the price forecasts have been accepted, a sensitivity analysis should be performed on a range of pricing outcomes (as with any other major cost or revenue driver), and risk mitigation evaluated. Risk mitigation through financial instruments is a specialty area and not covered in this book, but includes actions such as forward sales, gold loans, hedging currencies, put and call options, etc.

10.4.3 Historic prices and volumes

Most minerals and metals have very long histories of sales and prices, which can be found from an internet search. Some will show both quantities and prices for over 100 years. The World Bank Commodity Price Data (Pink Sheet) lists in Excel, monthly and annual prices

in US\$ from 1960 for energy, raw materials, agriculture and metals and minerals. The US Geological Survey is another good source.

Usually prices will be in US\$ of the day ('nominal' terms). To be meaningful they need US inflation pumped in backwards to convert them all into today's equivalent prices ('real' terms). These inflation factors are available in the World Bank Pink Sheet. An example of real and nominal historical pricing is shown in Figure 10.4.1.

FIG 10.4.1 - Nickel price history 1960 - 2010.

10.4.4 Price prediction methods

Companies and organisations in the mining industry have used a wide variety of methods to predict prices. No one method standing out as completely accurate in predicting the future based on current knowledge. Accuracy of price forecasts has always been a key risk, with some highly profitable mines being launched into a higher than predicted price environment that might have otherwise struggled, and vice versa. The best forecasting practices build on industry analysis and provide a range of outcomes for managers to develop plans for and include.

The mining industry has companies that boomed through no clever forecasting of their own, unlucky projects that commissioned as prices sunk and investors who believed distorted price forecasts and lost badly. The following outline of methods and motivations in the mining industry has been created especially for this handbook and probably will never appear in a marketing text book.

FORECASTING METHODS

'Forecasting' looks forward at demand and supply in the industry, and synthesises the future market. It tries to understand the various opposing forces that will be operating in the industry and therefore how prices might move. This should be the best method but it is difficult to obtain accuracy. Forecasting can vary from crude to very sophisticated. Possibly the most important benefit to the mine manager or study manager is not the detail of the actual price forecast (as these seem impossible to get right consistently) but the understanding of the industry and its markets. While an expected or mid-case point is needed, the manager and management team also need to appreciate the market possibilities and so can readily adapt to its evolution.

DEMAND/SUPPLY SYNTHESIS

Forecasts of the market for any metal or mineral normally assess future demand and future supply. As the research deepens so then does the awareness of the difficulties of making reliable forecasts of each side:

- simple studies make broad generalisations about demand and compare these with the output expected from mines as they phase in and phase out
- sophisticated studies need to forecast world gross domestic product, shifts in global economies, producer country and consumer country developments, structural changes in the industry, technology jumps in the end markets, exploration success, global resources and future reserves, technical changes at competitor mines, global political transformations, blockades, wars, tariffs – and much more.

In the long term, it is the thinking through these influences and being able to positively exploit better or worse market conditions that may be more useful than the price forecast.

PROJECTION METHOD

A common method is to graph the historical price, in nominal or real terms, and simply continue the trend and ‘project’ it out. Projections of high prices and low prices may be added (‘projecting’ is not ‘forecasting’).

The path of the projection may change dramatically depending on how many years are in the historical base. As would occur in the nickel price chart in Figure 10.4.1, a few years is likely to give a very different projection to one based on decades of history, which in turn may be different to 100 years of prices. An organisation using the ‘prejudice or bias method’ described above, for example, might select the history over the last three years because that projects high nickel prices.

ENHANCED PROJECTION METHOD

The ‘projection method’ above can be enhanced by experts interpreting the shape of the historical graph, explaining the ups and downs and then adjusting the projection for the market it expects (before being proved very wrong by the commodity price surge in the late 2000s there was a strong belief that prices would continue to decrease by one per cent real per annum and be matched by costs decreasing by one per cent real).

PREJUDICE OR BIAS METHOD

Prejudice and bias seem to be more common than one would think, and mine managers, study leaders and acquisition managers should be vigilant as to the degree to which bias and prejudice may be influencing the forecasts and subsequent asset values. Usually the influence is somewhat subconscious by preferring or overweighting more positive market drivers, but also including internal factors such as production volumes and operating costs. History has its examples of incompetent and unethical behaviour (extreme examples include the Poseidon nickel boom in the late 1960s and more recently the Bre-X fraud). In the extreme this may manifest itself where an organisation might know the level of future prices it needs to adopt to satisfy an external need and so becomes biased or prejudiced resulting in ‘forecasts’ higher than it would have derived from a wholly objective analysis. Using pseudo-marketing research, a favourable set of historical data is extracted, demand/supply is selectively analysed and the price forecast is presented with bold assertions about the market. Reasons for acting quickly may be given. Examples are:

- If a marginal project needs to be approved and financed, then the promoters will know the type of price forecast that will make the investment appear attractive.

- An organisation's project development team may have bonuses dependent on progressing a major project from one study phase to the next, so optimistic prices are adopted to get it through.
- Some companies have competent market research capabilities but when the price forecast is done by the most senior level of management, the CEO and board impose their own opinions based on their experiences, rather than on thorough market research. Commonly, conservatism is imposed in the name of prudence, whereas it may be as bad as being excessively optimistic.
- An organisation might give the stock exchange an ambitious production forecast, knowing it will be a challenge. Internally the organisation may give its mining engineers a forecast of high prices so as to lower the cut-off grades and inflate the material movements.
- Every organisation has its assets valued in its accounts. If price forecasts are lowered then some of these assets may need to be devalued, and the organisation would have to report an impairment (write-down) that is likely to reduce its share price. To avoid or minimise, the organisation might adopt a high forecast of price.

MARKET RESEARCH ORGANISATIONS

The market research can be done by a mix of in-house and external organisations. Bigger companies may be able to justify in-house staffing for their existing commodities and use external specialists for researching new commodities. Smaller companies tend to hire external market specialists for major research.

All the issues noted in Section 10.2.1 regarding managers not leading the price forecasting process and the risks of competence, poor analysis, bias and prejudice are equally as relevant to price forecasting.

PRICE FORECASTS

The price forecasts by in-house or external research organisations can range from simple to sophisticated. It is common for it to be in two parts: a short-term path that curves to meet the beginning of the long-term forecast. Many companies then fit two more price forecasts above, being 'high' and 'maximum', and two more below, being 'low' and 'minimum', such as the example shown in Figure 10.4.2. The long-term, mid-price frequently is a flat

FIG 10.4.2 - Nickel price forecast 2010 - 2036.

real price, but some companies adopt a declining curve or an inclining curve in real terms. Some companies try to incorporate market cycles within these forecasts. Other companies compare their preferred forecast to a range of published expected curves to also indicate how conservative or bullish their opinion is.

A danger of the more sophisticated price forecasts is that mine managers and study leaders become overwhelmed by the mathematics and drop back into deferring to the experts. Rather than getting inside their derivation and understanding their limitations, the forecast is adopted mechanically in their financial models. Instead the managers should be designing operations that match the price forecast but with the flexibility to adapt to whatever market might reasonably come and define trigger events to assist them in understanding how the forecasts are performing to expectations.

RECENT HISTORY

An experience of recent decades is that the forecasts have been unable to accept the magnitude of changes in global economics, especially on a regional basis. Thereby the mid-price forecast has been hopelessly out of touch and not even the maximums/minimums enclosed the subsequent actual prices.

NOMINAL OR REAL

A surprisingly frequent deficiency is that the graph and the associated table of numeric data omits whether the prices are in nominal or real terms, and if in real terms it does not specify the year. It is dangerous to guess. Occasionally in broker forecasts the short-term is in *nominal* terms while the long-term is in *real* terms.

10.4.5 Foreign exchange forecasts

Any price forecast must simultaneously forecast the foreign exchange rate ('forex').

These two should be seen as a pair. Forecasting price alone is abrogating this responsibility, and by default is stating that forex will remain as it is. Even in countries where the forex is not related to commodities, this relationship needs to be specified and not left undefined. Of course in countries like Australia and Canada there appears to be a strongly inverse relationship between price and forex, with a movement in one tending to be partly offset by a compensating move in the other. This can be seen in the daily price and forex movements offsetting each other to give the same A\$ price.

Most importantly, there must be a separate forex forecast for each price forecast. So the maximum price forecast needs its own forex forecast, the high price forecast needs its own forex forecast, etc.

ONE COMMON SOURCE OF MAJOR ERROR

A common mistake has been to test production plans for the impact of price without matching the forex. Too often mine or study managers have thought of prices moving by a large percentage, forgetting that forex might offset a large amount and then taxes further reduce the impact.

This pairing cannot be avoided by modelling in US\$. The capital costs, operating costs and taxes need to be modelled in local currency. The results and net present value should be the same in either way.

10.4.6 Price needed for zero net present value

When completing the economic evaluation of a project or of an investment the price forecast graph (for example the one shown in Figure 10.4.2) can be used to illustrate very clearly the price needed for zero NPV. It becomes very obvious whether this is comfortable, or as in the example in Figure 10.4.3, a stretch.

FIG 10.4.3 - Zero net present value matched to the nickel price forecast.

10.4.7 Detailed price calculations

Most metals and minerals have a global reference price from which the actual price achieved by the mine must be computed. The adjustments commonly are producer's location and quality (eg grade, credits and penalties, payable formulae agreed with customers).

SOURCES OF INFORMATION

Useful sources of advice are:

- marketing experts in that metal or commodity
- internet searches
- The AusIMM's publication *Cost Estimation Handbook*, 1993. Although dated³, it gives the principles and history.

PRODUCER'S LOCATION

Many metals are based on the price delivered to a specific location, such as into a London Metal Exchange (LME) warehouse (note that while the majority of product is shipped direct to customers, it is still the LME warehouse that is usually the basis behind the pricing). So the producer has to adjust price for the logistics of the freight to the nearest LME warehouse and the handling costs both ends. The starting computation is to assume this reduces the price received (LME price less freight and handling), but in some locations this can be a positive if a producer sells into a local market where its main competition is buying from the LME (local price = LME price + freight and handling).

3. At the time of writing, an update to this handbook is in preparation.

Commodities may have a global reference price based on the original or dominant trade route, such as free-alongside or loaded on to a ship at a certain location. Phosphate rock, for example, has its pricing reference as FOB a ship in a port of the world's dominant producer: Morocco. Where the mine is selling into a concentrate or bulk commodity market the transport costs will often become a cash cost rather than a pricing effect.

Gold is an exception, where the costs of delivery and refining usually are irrelevant compared with the accuracy of its price prediction.

QUALITY

Each metal and commodity adopts a standard physical and chemical specification. The price of each cargo is adjusted in price according to pre-agreed quality terms. These adjustments are normally based on a historical metallurgical cost in processing or a historical benefit/penalty in consumption. Increasingly, these quality adjustments will be refined by greater technical understanding and quantification of the positives/negatives as 'values-in use'. Energy coal has a reference price then a major price adjustment based on calorific benefit. Nickel's price will be adjusted for its form as pure metal, as ferro-nickel or as pure hydroxide. Raw diamonds have a reference price but individual rough stones vary from worthless to fabulous according to the carats, clarity and colour.

TWO MAJOR DANGERS IN BASE METALS PRICING

Base metals have a long history of price mechanisms that share the contained metal value between the mine and the smelter. These comprise a number of payment terms, which include the treatment charges (TCs) for smelting and refining charges (RCs). They are negotiated periodically between leading smelters and leading mines. Their origins lie in the furnace recoveries and costs of a century ago but their form has survived into the 21st century. The computations are relatively simple but involve many steps.

Most base metals companies put a lot of thought and effort into forecasting the 'LME' prices of copper, lead, zinc and nickel because these are so very important in managing the organisation. Marketing departments are usually requested to forecast the TCs and RCs, yet this requires the same of diligence and experience as price forecasting. The first major danger is that the organisation fails to realise that the forecast of TCs and RCs into the long term is so important to mine economics; they partly determine what proportion of the LME price the mine will receive.

Forecasts of the TCs and RCs need an assessment of the demand/supply balance between mines and smelters into the long term. Which side will be in shortage and so have negotiating power over the other? Will there be overcapacity in smelter capacity so that TCs will fall, or will there be overcapacity in mines so that TCs will be high? Payable metal formulae often (although decreasingly) include price participation mechanisms whereby a reduced percentage of the LME price is returned to the mine when prices are higher.

The second major danger is that errors are made whilst computing the TCs, RCs, minor metals and penalties. This happens too frequently, and on occasions with disastrous effects.

Mine managers and study leaders should insist that every economic model follow the Guidelines for Technical Economic Evaluation of Minerals Industry Projects (Appendix 1) and therefore has these computations as a long series of tiny step-by-step calculations where every piece of logic is visible and is easily checked. Mine managers should demand that graphs are created that show how the value of the metal in the concentrate is absorbed by payment terms, treatment charges and refining charges, as illustrated below in Figure 10.4.4.

Just as importantly, mine managers should demand a prominent calculation and a graph of how much of the contained copper was received by the mine, and this could be sense checked. The same would occur for contained lead, zinc, gold and silver. This needs to be done at two levels; firstly as percentages of metals in the ore to understand the orebody and again as percentages of metal in the concentrate to understand the smelter/mine sharing, as illustrated in Figure 10.4.5.

FIG 10.4.4 - Examples of revenue calculations for copper and lead.

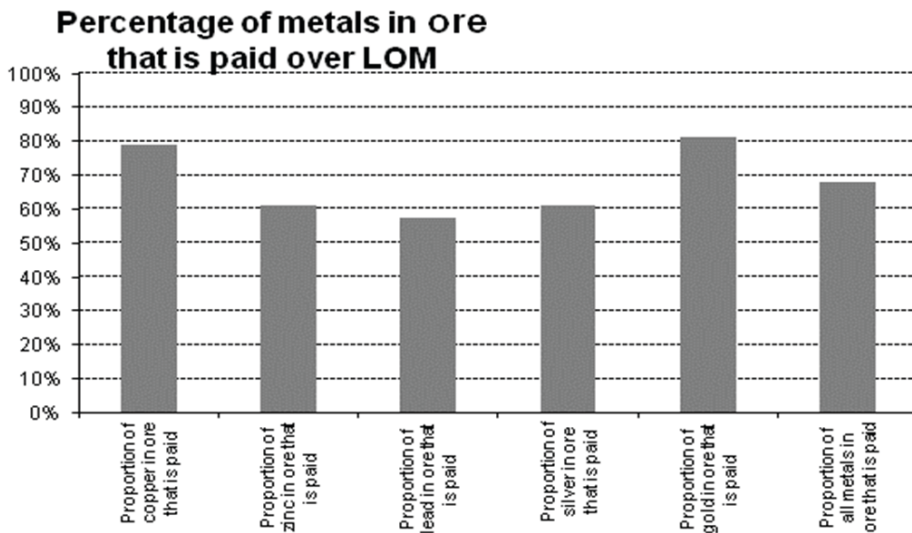


FIG 10.4.5 - Examples of 'payable' metal ratios for base metals.

AN ALTERNATE AND POSSIBLY SUPERIOR FORECASTING METHOD FOR BASE METAL MINES

Mine managers should decide if the forecasting of concentrate payment terms should be drastically simplified and more easily controlled by being turned on its head. The computation would use the percentage of each metal in the concentrate paid to the mine and avoid all the complex mechanical algorithms. Mine managers would seize control rather than be side tracked by detail.

10.5 RISK MANAGEMENT

This guide to risk management is designed to help mine managers identify key risks to outputs, whether for the operation, team or individual activity. Managing risk enables the organisation to achieve its potential, with the least interference from a risk consequence eventuating. Effective risk management also enables managers to take advantage of opportunities as they arise.

Risk management applies to all minerals operations in general; including outsourcing and outsourced services, contract management, program delivery, public events and enabling services. Risk management enables managers to minimise the barriers to meeting the organisation's objectives.

Risk management isn't just about decisions and behaviours that affect expenditure or expose the operation to liability. Risk management is about giving the best advice possible to general management and other stakeholders.

10.5.1 About this section

This guide is based on the previous Australian/New Zealand Standard AS/NZS 4360:2004 – Risk Management (the old Standard) now superseded by AS/NZS ISO 31000:2009 Risk Management – Principles and Guidelines – and describes how to meet the requirements of the Territory's Risk Management Policy Statement. For further details on any aspects of risk management, please refer to:

- the Standard (<http://www.standards.com.au>)
- the ACT Government's Enterprise-Wide Risk Management Framework.

10.5.2 A definition of risk

A risk is defined by the Australia/New Zealand Standard for Risk Management as:

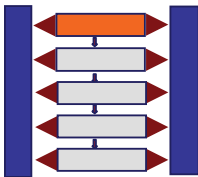
... the possibility of something happening that impacts on your objectives. It is the chance to either make a gain or a loss. It is measured in terms of likelihood and consequence.

The effective management of risk enables one to maximise opportunities and achieve outputs.

The risk management process is illustrated in Figure 10.5.1.

10.5.3 The steps involved in managing risk

ESTABLISH GOALS AND CONTEXT



As outlined in the risk management process, the risk assessment is undertaken within the context of set goals. The identification/validation of goals is therefore a critical first step in the risk management process.

Effective risk management requires a thorough understanding of the context in which the operation functions. The analysis of this operating environment enables managers to define the parameters within which the risks to outputs need to be managed.

The context sets the scope for the risk management process. The context includes strategic, organisational and risk management considerations. According to the Standard, strategic

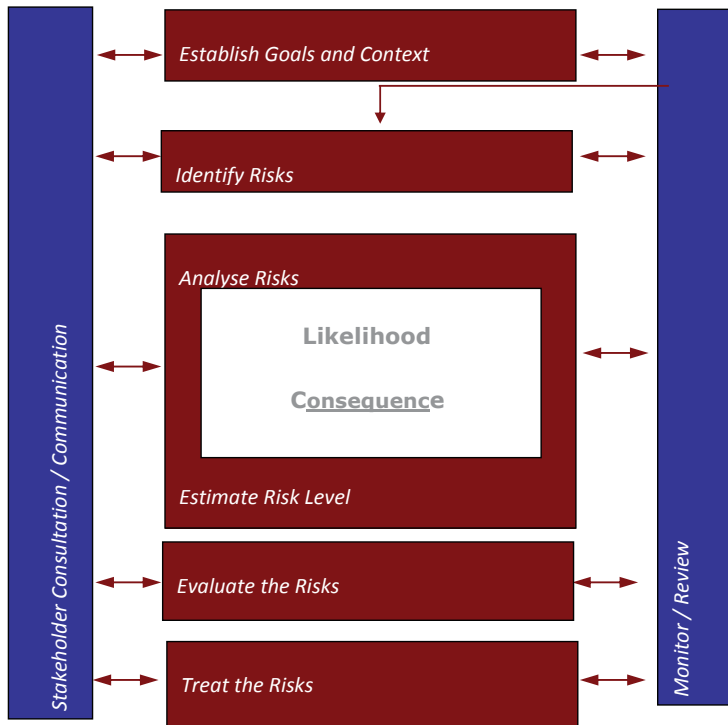


FIG 10.5.1 - The risk management process.

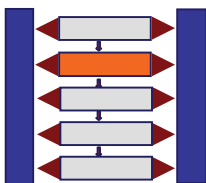
context defines the relationship between the organisation and its environment. Factors that influence the relationship include financial, operational, competitive, political (public perceptions/image), social, client, cultural and legal. The definition of the relationships is usually communicated through frameworks such as SWOT (see Section 10.1.4) and the political, economic, societal and technological (PEST).

The organisational context provides an understanding of the organisation, its capability and goals, objectives and strategies. According to the Standard, organisational context is important because:

- risk management occurs within the context of endeavouring to achieve the goals and objectives
- failure to achieve the objectives is one set of risks that need to be managed
- the goals and strategies assist to define whether a risk is acceptable or unacceptable.

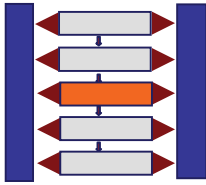
The risk management context defines that part of the organisation (goals, objectives, or project) to which the risk management process is to be applied.

IDENTIFY RISKS



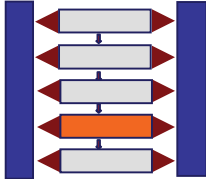
Identify the risks most likely to impact on the outputs, together with their sources and impacts. It is important to be rigorous in the identification of sources and impacts as the risk treatment strategies will be directed to sources (preventive) and impacts (reactive).

ANALYSE RISKS



Identify the controls (currently in place) that deal with the identified risks and assess their effectiveness. Based on this assessment, analyse the risks in terms of likelihood and consequence. Refer to the risk matrix (<http://www.treasury.act.gov.au/actia/toolkit.doc>) to assist in determining the level of likelihood and consequence, and the current risk level (a combination of likelihood and consequence).

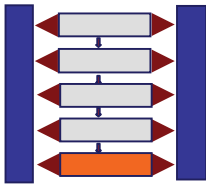
EVALUATE RISKS



This stage of the risk assessment process determines whether the risks are acceptable or unacceptable. This decision is made by the person with the appropriate authority. A risk that is determined as acceptable should be monitored and periodically reviewed to ensure it remains acceptable. A risk deemed unacceptable should be treated (see below). In all cases the reasons for the assessment should be documented to provide a record of the thinking that led to the decisions. Such documentation will provide a useful context for future risk assessment.

DETERMINE THE TREATMENTS FOR THE RISKS

Treatment strategies will be directed towards:



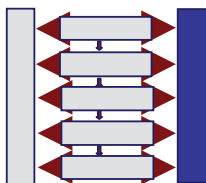
- avoiding the risk by discontinuing the activity that generates it (rarely an option when providing services to the public)
- reducing the likelihood of the occurrence
- reducing the consequences of the occurrence
- transferring the risk
- retaining the risk.

Potential treatment options are developed according to the selected treatment strategy. The selection of the preferred treatment options takes into account factors such as the costs and effectiveness.

The determination of the preferred treatments also includes the documentation of implementation details (eg responsibilities, a timetable for implementation and monitoring requirements).

The intention of these risk treatments is to reduce the risk level of unacceptable risks to an acceptable level (ie the target risk level). Use the Risk Matrix (<http://www.treasury.act.gov.au/actia/toolkit.doc>) to determine the expected reduction in level of risk (expected consequence, likelihood and target risk level) resulting from the successful implementation of the treatment.

MONITOR AND REPORT ON THE EFFECTIVENESS OF RISK TREATMENTS



The relevant manager is required to monitor the effectiveness of risk treatments and has the responsibility to identify new risks as they arise and treat them accordingly. Managers are also required to report on the progress of risk treatments at regular intervals. The person who has the responsibility for a risk treatment is expected to provide feedback on the progress of the 'project/initiative' as detailed in the 'monitoring' field of the treatment.

10.5.4 Risk management in the corporate context

In managing risk, it is the organisation's practice to take advantage of potential opportunities while managing potential adverse effects. Consequently, a formal policy should be drafted that sets out a summary of the organisation's risk management system and processes, and the organisation's risk profile.

The main features of such a corporate policy are summarised below and set out in more detail in Appendix 4:

- role of the board and delegated responsibility
- role of the managing director and accountabilities
- authority of the managing director
- risk profile
- additional policies and practices
- responsibility to stakeholders
- continuous improvement.

10.5.5 Risk management in the mine site context

A practical guide for the application of these principles is set out in Appendix 4. Risk likelihood and consequence matrices are worth assessing with input from a multi-disciplinary team drawn from the mine. In addition, there is value in extending the matrices across five areas of consequence namely:

1. injury
2. financial loss
3. environmental damage
4. reputational harm
5. value improvement.

In each case, risks may be managed by a combination of elimination, substitution or reduction. Software is available to assist in this process⁴, which generally consists of a simple spreadsheet tracking approach.

Risk management is now a compliance matter at board level and as a consequence of that, it is likely that the same will be required of all mine sites. From this situation, an upward and downward flow of actions will emerge as part of the overall process.

Risk management matrices are usually updated on a regular basis: at board level this may occur yearly, but at the operations level, a more frequent, task-based, review is recommended.

REFERENCES

- Lane**, K F, 1988. *The Economic Definition of Ore: Cut-off Grades in Theory and Practice* (Mining Journal Books: London).
- Schaap** W, 1986. Optimum scale of an open pit operation – Discount rate and risk, *Proceedings of The Australasian Institute of Mining and Metallurgy*, 291(5):49-54.

4. One example cited here is the Bsafe software.

APPENDIX 1

GUIDELINES FOR TECHNICAL ECONOMIC EVALUATION OF MINERALS INDUSTRY PROJECTS

APPENDIX CONTENTS

Introduction to the Guidelines for Technical Economic
Evaluation of Minerals Industry Projects

B White

1 Introduction

2 Guidelines for Spreadsheet Modelling

- 2.1 Purpose
 - 2.2 Key principles
 - 2.3 Easy to follow
 - 2.4 Tailored-to-purpose
 - 2.5 Transparent
 - 2.6 Disciplined, rigorous and consistent
 - 2.7 Recording sources of all data
 - 2.8 Rapid to audit
-

3 Guidelines for Economic Evaluation

- 3.1 Purpose
 - 3.2 Context
 - 3.3 Process
 - 3.4 Alternative evaluation and assessment methodologies
-

Appendix A – Worked example

Appendix B – Introduction to discount rates

Appendix C – Recommended reading list

Appendix D – Technical Economic Evaluation Guidelines committee
members

INTRODUCTION TO THE GUIDELINES FOR TECHNICAL ECONOMIC EVALUATION OF MINERALS INDUSTRY PROJECTS

The standards and practices employed in the process of evaluating projects, the application of economic-styled valuation techniques and, by implication, the spreadsheet modelling protocols applied, are matters that are of concern to members and the industry generally. The development of guidelines for technical economic evaluation and spreadsheet modelling is seen as beneficial as the economic evaluation of projects and business opportunities is a regular feature in our sector. Also, coupled with such assessments are numerous technical assumptions about geology, mining and metallurgical parameters along with an expectation of accurate modelling and application of the discounted cash flow valuation methodology. The consideration of these items is often in the hands of the analyst and project team immediately undertaking the evaluation with no reference to an industry standard aimed at providing guidance on these combined tasks.

The AusIMM has undertaken to assist the mining industry in establishing standards and practices for the technical economic evaluation of mines, projects, processes and businesses. The Guidelines represent a collation of sound practices that competent practitioners in economic evaluation have developed over the years, and cover what is considered good practice in both spreadsheet modelling and technical economic evaluation.

The Guidelines are, as the title states, for technical economic evaluation. They are primarily directed at an analyst or evaluator with a technical, rather than financial, background. They will typically be applicable to a wide range of projects, from, for example, the justification of the purchase of a piece of capital equipment by a relatively junior engineer on a mine site, to the evaluation of a complete project or property. The primary focus is on the technical economic evaluation, which is intended to identify the viability of a project in its own right, independently of any decisions as to how it might be financed.

The Guidelines do not deal with what one might term the engineering aspects of the project: the level of accuracy of the evaluation; the methods of deriving various physical inputs such as construction quantities, Ore Reserves and mine schedules; and sources of cost information. Neither do they deal with, for example, the various alternative treatments of such things as taxes in various jurisdictions and depreciation, nor the mechanics of their calculations. It is implicit that all inputs and calculations will need to be done with the degree of process, skill and detail appropriate to the level of accuracy of the study being undertaken. The technical economic evaluation is only a part of the total study, albeit a very important part that, in one sense, pulls all the various non-financing activities together.

The Guidelines for Spreadsheet Modelling, which are an important component of these Guidelines, outline the key principles and mechanics that should be adopted, not only for economic evaluation modelling, but also as current best practice guidelines within our industry for any spreadsheet modelling exercises. It is recommended that these Guidelines are applied by companies, organisations, consultants and individuals whilst recognising that their adoption is voluntary and not strictly mandated.

The Spreadsheet Modelling Guidelines identify a number of key principles to which one should adhere for spreadsheet modelling to be simple but effective. They are:

- easy to follow
- tailored-to-purpose
- transparent
- disciplined, rigorous and consistent
- recording sources of all data
- rapid to audit.

1 INTRODUCTION

The Australasian Institute of Mining and Metallurgy (The AusIMM) is the leading organisation representing technical minerals sector professionals in the Australasian region. Members are bound by a Code of Ethics and continual improvement of professional and industry standards within the sector in which they work.

The minerals industry has a poor history of decisions being underpinned by faulty economic evaluation modelling. These have ranged from minor mine-site decisions to major corporate acquisitions. Too often the modelling was convoluted, sophisticated and personalised, so audit was tedious and frustrating. Consequently, people at all levels have called for simple evaluation models. What they mean is modelling that is easy-to-follow even when the subject is complex and so the model becomes long and detailed. If the models are made to be transparent, intuitive and fast to audit then these errors can be eliminated.

The AusIMM has taken up this challenge and established these *Guidelines for Technical Economic Evaluation of Minerals Industry Projects*. It is a collation of sound practices that competent practitioners in economic evaluation have established over the years for the technical economic evaluation of mines, processes, projects, studies, businesses, companies and industries.

These modelling practices are easy to understand and fast to adopt. The initial model might take fractionally longer to create, but from then on any use, updating, expansion, modification and checking is much faster – especially for others. The resulting model is easier and faster to audit. If the evaluation person is suddenly unavailable then others can take a copy and use it confidently. The model is friendly and intuitive for everyone. The modelling style does not belong to one person but is familiar across the minerals industry and is rigorous. Errors in logic and data are easy to identify. The model becomes a useful tool for all, helping to steer the project and giving confidence in the results.

The practices are described immediately below in Section 2: Guidelines for Spreadsheet Modelling. There is no support for a prescribed method, a universal model or a black box model. Instead a worked example is shown in Appendix A.

Section 3: Guidelines for Economic Evaluation is not part of the core purpose but is the sharing of experiences and approaches at a high level. Appendix B is a brief introduction to discount rates for analysts who do not have financial training.

The Guidelines are recommended for:

- day-to-day assessment of operations at mine sites
- highly technical studies
- projects and studies
- corporate and company-wide models
- major corporate decision making.

They are recommended for adoption by:

- evaluation specialists, whether from an operating, technical or commercial background
- consultants who need to be transparent in their advice
- technical specialists, even if the model is not for economic evaluation
- plant managers who demand that assessments be readily understood

- project managers and study leaders who demand that the economic evaluation be an easy-to-use working tool that helps steer the project, even if the project is most complex and so the model evolves to be long and detailed
- senior decision-makers in companies and organisations who want simple evaluations (they usually will not interrogate the model but must be confident there are no hidden major errors).

Users are requested and encouraged to forward any suggestions for improvements, correction of errors, etc to the AusIMM's editor.

2 GUIDELINES FOR SPREADSHEET MODELLING

2.1 Purpose

The Guidelines for Spreadsheet Modelling outline the key principles and mechanics that should be adopted, not only for economic evaluation modelling, but also as current best practice guidelines within the industry for any spreadsheet modelling exercises. It is recommended that these Guidelines are applied by companies, organisations, consultants and individuals, whilst recognising that their adoption is voluntary. A worked example that serve to illustrate these principles and the mechanics (along with those for the Guidelines for Economic Evaluation) is provided in Appendix A.

The following discussion uses the terminology and nomenclature used by Microsoft Excel™, which is the software used almost universally by industry practitioners. The same principles, however, apply regardless of the software used.

2.2 Key principles

The key principles one should adhere to when spreadsheet modelling are simple but extremely effective. They are:

- easy to follow
- tailored-to-purpose
- transparent
- disciplined, rigorous and consistent
- recording sources of all data
- rapid to audit.

They make the model intuitive and readily followed even when it becomes long and detailed.

2.3 Easy to follow

2.3.1 INTUITIVE AND VISUAL

'If you cannot readily understand my model you do not have a problem, I do!'

A person unfamiliar with the organisation should be able to receive the evaluation model remotely and be able to readily understand and follow the evaluation from beginning to end:

- The whole workbook should have an obvious visual flow from left to right, across labelled worksheets and down each worksheet.

- Within each worksheet, the columns and rows should have obvious visual flows just like a simple text book.
- The titles and subtitles used in each sheet should cascade like one would see in a contents page.
- The workbook should begin with a brief introduction that explains the purpose and context of the document and how to interpret the formatting for faster understanding.
- Each worksheet should have its bold heading followed by an outline of its purpose and its broad links with other worksheets. Sections within each worksheet should be discrete, with obvious inputs, computations, outputs and graphs.
- Every cell should adhere rigidly to the formatting convention and so can be interpreted visually.

This principle should not be seen as a requirement to dumb down a model of complex processes. It means that every part should be intuitive, even to non-experts.

2.3.2 TIME TO DO IT PROPERLY

‘Like painting a room at home it is 90 per cent preparation’:

- time should be taken to understand the activity being modelled from raw material inputs to finished product outputs, be it a business activity, a technical activity or an intellectual activity
- the evaluation model should be built speedily but carefully and methodically, rigorously using the modelling practices, so as to be easy-to-follow and making any errors recognisable during a quick audit
- shortcutting of modelling practices frequently produces hidden errors because there is inadequate transparency, consistency and rigour
- before any results are released, graphs should be generated of the key inputs and results as essential checks
- before any results are released the model should be properly audited – internally, then by an external party.

2.3.3 ARCHITECTURE – WORKBOOK LAYOUT

The model’s architecture should be intuitive, even to a non-expert, so that its structure is obvious and navigation around the parts of the model is rapid:

- There should be complete flexibility in the way the model is structured. Some models will evolve from one worksheet to multiple worksheets as more detailed modelling is justified.
- The flow of multiple worksheets should be a logical sequence from left to right. Each worksheet has a tab name that shows its purpose.
- Usually the model should be saved so that it opens at the top of the first worksheet, where there is a brief description of
 - the purpose of the model
 - contact details of the author and users
 - the directory location where it is securely stored
 - the model’s architecture if there are many worksheets
 - any warnings or limitations
 - audits completed

- the modelling practices/formatting
- list all other models that are used for inputs or that are directly linked.
- The model should then include a summary of results and key inputs in numeric and graphic forms. The modelling may commence under that summary but more commonly on subsequent worksheets.

2.3.4 WORKSHEET LAYOUT

A non-expert should readily understand the function of each worksheet, how it is arranged into component parts, how the data is entered, the computations and the relative importance of the parts:

- The visual flow down and across each worksheet should be intuitive and logical.
- Each worksheet should have a bold heading followed by a brief outline of its purpose, and, where helpful, its important links with other worksheets.
- Sections within each worksheet should be in discrete work blocks, with obvious subsections and subheadings using a cascading layout for subtitles.
- Visually each work block should be self-contained with an obvious step-by-step development toward a bold subtotal for that work block.
- The separate work blocks should be in a logical sequence down and across the worksheet and their aggregation be obvious.
- Complex and extended computations should be shown in a series of small steps so that the logic is visible and the input parameters are obvious. There should be no need to interrogate the algorithm. Explain the logic of complex algorithms in a visible row note.
- Usually if a row of data that has already been presented above is needed again in a work block then the entire row should be repeated so that there is visual flow of the logic. If referenced from another worksheet then it should be colour-coded.
- Key inputs and results should be shown in graphs as a self-check and for rapid understanding.
- The 'Data / Group' outline facility can be used to define worksheet structure, collapse related groups of rows or columns to reduce visual clutter, and aid navigation.
- Each worksheet should have a header and/or footer so the source, date, etc can be identified when looking at printed copies.

2.3.5 MODULAR CONSTRUCTION

As much as possible, the model should be constructed as modules, each having a clear set of inputs, calculations and outputs that are used in various other calculations downstream, or presented as final results:

- Calculate any parameters only once in the whole workbook, then use that one result in all other places where it is required. Changes need only be made in one place, rather than having to search through the model to find all places where the same parameters have been calculated.
- The testing of small independent modules facilitates error-checking and auditing.

2.4 Tailored-to-purpose

2.4.1 SIZE AND COMPLEXITY

Greater sophistication and mathematical complexity does not automatically deliver a better model:

- some major decisions and risks can be evaluated with small, simple models, whereas some minor investigations require elaborate mathematical modelling
- in general, the size of a model increases as a study progresses through conceptual, prefeasibility and feasibility levels but every model should match the materiality of a parameter to the detail of its computation
- long and detailed models may be required for some tasks
- increasing detail and size decreases the model's universal appeal, including its auditability
- where a long and detailed model is required it should be made easy-to-follow
- intellectual prowess should be used to transform complexity into small steps
- modelling should proceed as a series of visually easy-to-follow steps rather than using complex algorithms and inbuilt software functions
- models should take the reader through the logic process in small steps rather than using a 'trust my modelling' approach in a single cell or complex algorithm/function
- there is a level of detail necessary to get a good outcome, but a more detailed level of analysis may be required to prove that it is good, particularly where results are counter-intuitive or unexpected.

2.4.2 MINIMALIST – AS SIMPLE AS APPROPRIATE

- Each evaluation should begin with the thought of having the entire activity sensibly represented in one worksheet.
- As the model matures and expands it is preferable to have only one main model to handle all the variations. It is difficult to manage and control multiple versions of the same model for different scenarios, especially when more than one person is using them or if a retrospective change needs to be made to each version.
- It may be useful to have stand-alone submodels that evaluate subordinate issues. Once resolved the outcome should be incorporated into the main model.
- In a long and detailed model it may be helpful to have a diagram in the front 'Introduction' worksheet showing how the model's sheets interact and flow.
- Models should be commenced as minimalist. Computations should not be included in case they may be needed in the future. However, as part of the overall project specification, model capabilities that might be needed should be identified at the start of the project and the model constructed in such a way that they are not precluded and can be easily added later if required.
- Extra detail may be introduced when the extra rows of computations are justified.
- Computations, where used, should be stepped-out row-by-row without skipping obvious steps. Algorithms should be kept short so as to make the model easier to understand and follow.
- Computations should also not be complicated by mixing multiple activities, eg having a mathematical formula that models the process and also includes a change in units.
- Some results may be computed to sufficient precision using simple approximations. For example
 - operating costs may be simple fixed and variable until a detailed bottom-up computation is warranted
 - mineral concentrate prices may be better computed as a percentage of contained values rather than using the detail of complex historical pricing mechanisms.

- However, care must be exercised, as simple relationships will typically have a smaller range of validity than more complex relationships, which may limit the range of sensitivity analyses that can be validly conducted. The limits of the validity of simple relationships should be ascertained and clearly specified in a visible row note above the associated data items or calculations.

2.4.3 MATCHING DETAIL AND CONTENT WITH ITS IMPORTANCE

Computations should be tailored to match their importance:

- The computations that have greatest impact on the result should be given the most attention.
- The computations of secondary and tertiary importance should be given less priority and detail.
- Computations that are a focus of a particular person should not be given undue attention, for example working capital by an accountant.
- Income tax and working capital may be approximated in a few coarse computations, rather than to accounting detail.
- Accounting statements should be derived from the technical-economic cash flows, rather than vice versa.
- It is recognised that some key decision-makers and influencers may have strongly-held views, which may need to be proven or disproven by extra evaluation detail.
- Select appropriate time-scales for calculation of physical quantities, cash flows and reporting. These may all be different. There is a trade-off between accuracy, complexity and model size
 - small time increments (eg daily, weekly, monthly) may be too detailed for the level of study, imply an accuracy that does not exist and increase the model size unnecessarily
 - large time increments (eg yearly) may be too coarse for some purposes, requiring complex logic to handle interactions between time periods (eg if the model is generating automated schedules with predecessor/successor relationships)
 - an intermediate time frame (eg quarterly, half yearly) may provide a balance between the various considerations
 - smaller modelling time increments can be easily summarised for final reporting of results.

2.4.4 MATCHING DATA AND CALCULATIONS

- Create data entry areas in a layout that makes it easy and natural for the user to understand and to enter the right data accurately.
- If necessary, preprocess the entered data to convert units used or into a different format that facilitates the development of simple, robust, error-free model logic
 - do not force the user to enter data in an unnatural way simply to suit the calculations
 - do not develop complex logic just because the data is entered in a particular way.
- Do calculations in unfactored units, eg tonnes, dollars, etc (this does not affect calculation time or internal precision of floating point calculations)
 - Use grades and recoveries as decimal fractions (values between 0 and 1), not as percentages (values between 0 and 100). Make use of the spreadsheet's number formatting features and styles to display percentages.

- Avoid multiplying and dividing by 100, 1000, 1 000 000, etc in the body of the model. This is error-prone and adds unnecessary computations. Make use of the spreadsheet's number formatting features and styles to round the display to show thousands, millions, etc.
- Preprocess raw data once by these unit and/or scaling conversion factors if necessary before further use in the model.
- If exporting results to another model, create an export worksheet in the format required by that model, and do any unit or scaling conversions necessary (to percentages, thousands, millions, etc) when populating the export sheet.

2.4.5 DIRECT INVOLVEMENT OF PROJECT TEAM MEMBERS

Key team members may assist with the creation of the model in their areas of expertise:

- their enthusiasm for lots of detail to replicate the intellectual challenges of their special areas should be tempered by and matched with the relative level of importance
- they should audit their own part of the model and so co-own the model.

2.4.6 HELICOPTER VIEW

Each team member needs to gain a working helicopter view of the modelling. Focus is given to the areas that matter the most. Work on intellectually stimulating but minor issues should be minimised

A summary section with graphs of key assumptions and results should appear near the front of the model to give team members and management a readily understood overview.

2.5 Transparent

2.5.1 THE COMPLETE EVALUATION FLOWS LIKE A SIMPLE STORY BOOK

- By starting at the top of the first worksheet and reading on screen or printing to the end of the last worksheet the inexperienced, non-expert should be able to readily follow the logic
- non-expert readers should be able to readily understand how the model works and how its component parts fit
- the architecture and adherence to good/recommended modelling practices should make the evaluation transparent
- it should be easy to visually distinguish between
 - input of raw data
 - referencing of data from other worksheets
 - computations
 - outputs
- every worksheet and every cell should have a purpose and genesis that is obvious on the screen and in print.

2.5.2 INPUT DATA IS EXPOSED

- Every piece of input data should be entered in a prominent coloured input cell before it is used in an algorithm.

- No input should be hidden in an algorithm, with the possible exception of everyday conversions, such as dividing by thousands or converting pounds to kilograms. However, it is recommended that unit conversion factors also be entered once, and referred to where required. This avoids typographical errors or inconsistencies (eg the number of significant figures used) when the same factor is entered multiple times in multiple locations, and potentially at different times and by different people.
- A specific font colour should be used to readily identify data inputs. Blue is commonly used.
- Appropriate use of controls (eg drop-down boxes, check boxes, etc) can show the ranges or specific options for data values and scenario settings that may be validly used in the model, and limit entries to these.

2.5.3 DUBIOUS DATA IS HIGHLIGHTED

- A distinctive colour-coding system should be used to highlight input data or computations that are dubious or very preliminary. Pink may be used.

2.5.4 SOURCE OF DATA IS RECORDED

- All data sources should be recorded (see section 2.7)
- a number of columns with historical data from previous years may be useful – this will help demonstrate the veracity of forecast data.

2.5.5 ALGORITHMS FLOW VISUALLY

- Visually, the sequence of computations should flow like a simple story book down and across the spreadsheet.
- Complex algorithms should be broken into easy-to-follow steps.
- Computations should appear obvious and generally should not require interrogation of cells.
- Any change or inconsistency in a sequence of algorithms across a row (or down a column) should be highlighted.
- Links to other workbooks can be dangerous because the other model may be altered without the change being recognised. If links to other workbooks are used, the whole row/column with titles and labels should be referenced across so that covert changes can be seen. The linked row should be highlighted in colour.
- Macros that perform calculations cannot be readily followed visually or audited and generally are not trusted.
- Some spreadsheet functions have a history of misuse and cannot be audited, whereas longhand computations can be followed easily and visually.
- Multiple recalculations of the same thing should be avoided.
- If creating new logic that supersedes existing logic it is recommended the modeller either
 - label the old logic clearly as superseded, and preferably move it away from the active logic, eg to the bottom of the sheet, or
 - delete the old logic, but log the change, identifying the superseded version of the model that used it.

2.5.6 LANGUAGE IN FULL

- Units and technical expressions should be expressed in full at least once in a model. Consider using a list of abbreviations or a glossary of terms. Abbreviations such as ‘t’, ‘T’, ‘m’ and ‘M’ have different meanings to different people – some of which are not consistent with international standards. Examples include dry tonnes and wet short tons.
- If an algorithm requires data from another worksheet then the complete row is first referenced across, usually just above where it is needed.
- Every row that is referenced from another worksheet is shown in a distinctive colour-coding and/or font style.
- This means that every algorithm uses data already shown in its own worksheet. Auditing an algorithm will never show data that is referenced or linked from another worksheet.

2.5.7 REFERENCING OTHER WORKBOOKS IS AVOIDED

- Links to worksheets in other workbooks should be treated with extreme caution. If done, it should be obvious, limited to special situations, and done with extreme care. The whole row or column or rectangular range should be linked across. A distinctive cell format should highlight such imports.
- Ideally this should only be done for importing data that will change infrequently (or not at all), often preprocessed into suitable table structures or summaries for use in the model. (Examples might include tables of Ore Reserves generated from data extracted from geological block models and mine planning software, or fixed and variable unit costs derived from detailed cost records.)
- Information from other workbooks should always be imported directly into cells similar to data entry cells with no other processing, and then used in calculations elsewhere. Formulas in a cell should never both import data from another workbook and perform some calculation on or with that external information.
- Separate external data files should be maintained for each version of such data, links from the main model should be carefully checked regularly.
- Information identifying the data version should be imported from the linked workbook as well as the data itself, so that it can be easily seen what is being used without having to edit the linkages.
- Calculation logic that flows from one workbook to another and back to the first should be avoided, as changes made early in the logic in the first workbook will not flow correctly to later stages of the logic if the other workbook is not open or links both ways between the two workbooks have not been correctly maintained. Such links can easily be broken if one workbook is saved with a new name while the other is closed.

2.6 Disciplined, rigorous and consistent

2.6.1 TRUST WHAT IS SEEN

- What is seen on the screen or in print should represent what is happening in each row, column and cell.
- Every cell should adhere rigorously to the modelling practices that are shown at the start of the model.

- Every cell should be able to be trusted to be consistent with its neighbours of the same formatting.
- Any inconsistencies in algorithms should be highlighted.
- Worksheets, columns or rows should not be hidden. The 'Data / Group' facility is acceptable because it marks the collapsed data.

2.6.2 DISCIPLINE AND RIGOUR

- Either use 100 per cent modelling practices or zero practices. Models that follow the practices in the main but that covertly falter in other parts are far worse than models that have no practices.
- Time should be allowed to use the modelling practices and properly audit the model before results are expected.

2.6.3 AGGREGATES AND TOTALS

- Totals and subtotals should be obvious. It is recommended that a column on the left side of the spreadsheet is used, where it is usually visible, rather than on the right. Total rows should be highlighted with bold font or borders.
- Each sequence of numbers being inputted (row and/or columns) should be aggregated and these totals made obvious so that they can be readily understood and can be checked against source data.

2.6.4 COLUMN HEADINGS

- The sequence of columns across every worksheet in a workbook should be identical unless clearly identified, especially for year (or other time period) headings.
- Once a sequence of column headings is established in one worksheet it should be maintained in all other worksheets. For example, if the year 2018 is in Column K in one worksheet then it should be in column K in all worksheets. Exceptions should be clearly highlighted.

2.6.5 READY-MADE MODELS AND WORKED EXAMPLES

- Models with blank input fields to be filled for entry into a black box should be used with caution
- worked examples of these AusIMM modelling practices can be used as the starting point for a new model and adapted.

2.6.6 LOG OF CHANGES AND MODEL VERSIONS

- Where a history of changes to the model needs to be recorded, version numbers should be given to the models, and these should be recorded in all outputs, such as reports, presentations, etc (ie include file name, worksheet, date and revision in footer or printed cell for published outputs).
- The model distributed or used for report tables and figures should be the last with that version number. Any subsequent work done should be with the next version number.
- Anyone editing the model should list all updates in a separate log sheet within the workbook. The log of changes should include
 - o date and person

- o a description of the update (with figures noted), new NPV figure, etc
- o comments describing any reconciliation/explanation of the effect (if required).

2.7 Recording sources of all data

2.7.1 ROW NOTES OF THE SOURCE OF THE DATA

- Anyone reading the model should be able to immediately identify the source and date of the data, and so assess whether it is the most recent and appropriate.
- This applies to every row of numerical input values and to computational logic that is unusual.
- The source of each item of information should be recorded with the date, person and/or document name.
- This should show as a row immediately above or below the inputted data and always appear in full on the screen or in print. It is recommended that notes not be in a hidden, embedded cell note.
- Any source data that is known to be dubious or to need checking should be identified in a specific font colour. Pink or magenta is widely used.
- At the beginning of the model the name of the person performing the modelling should be stated, with their contact telephone and/or email address and the start date.
- Discipline is required to update source information when data is updated. There is little or no way to check on this later if it is not done at the time.
- It may be useful to retain previous data sets, with capability in the model to switch between them. In this case data source information might be entered in a particular column in each data row, and it will be more evident if some data sets have the same or no source information.

2.8 Rapid to audit

2.8.1 SPEED

- If the practices have been followed rigorously the model should be easy to follow and therefore quick to audit. Consequently, people are likely to be more willing to audit others' models.

2.8.2 PROCESS OF AUDIT

- Three phases of audit are recommended
 1. self-audit by the person who developed the model
 2. audits by internal members of the team who check their own sections
 3. a formal audit of the entire model by an independent person(s) external to the model
- the status of each of these three audits should be clearly visible on the Introduction worksheet.

2.8.3 AUDITING REPORTS BASED ON THE EVALUATION

- The person auditing the model usually should also audit the relevant sections of any reports based on that model
- the interpretation of model results over the ranges of cases needs to be confirmed.

2.8.4 AUDITING MECHANISMS

- A common approach to audit is to work from the key outputs, such as NPV or production, back up the streams of computations to the inputs for each.
- Create error checking formulas within a model. The more of these formulas in a model the more self-auditing it becomes.
- The total for each data input over the life of the evaluation should be checked against the source data. Global totals of key inputs and outputs should be tested.
- Where the evaluation is part of a larger-sized resource or organisation its validity and context should be investigated.
- Use of spreadsheet auditing/checking software should highlight inconsistencies and the use of data values hard-wired into formulas.
- Consistency of algorithms across rows and down columns may be tested by copying the algorithm in the first row across/down all others. It is not uncommon for the first column to be different, though that should be highlighted. Copying the second column may be better.
- Audit down columns is better done in other than the first column – in case the first column was altered but mistakenly not copied across, or is different from the rest for some valid reason (in which case the difference should be highlighted).
- When auditing, it can be useful to create a new sheet at the front of the workbook with
 - all auditing notes listed
 - a prioritisation colour-code noting high-, medium- and low-ranked items (using red, yellow and green cell colouring)
 - links to the sections of the model that the auditing notes apply to.

3 GUIDELINES FOR ECONOMIC EVALUATION

3.1 Purpose

The Guidelines for Economic Evaluation discuss key concepts and mechanics in economic evaluations and are independent of the Guidelines for Spreadsheet Modelling. It is recommended that these Guidelines are applied by companies, organisations, consultants and individuals as current best practice guidelines, whilst recognising that their adoption is voluntary. A worked examples that serves to illustrate these principles and the mechanics (along with those for the spreadsheet modelling) is provided in Appendix A.

3.2 Context

3.2.1 THEORY AND COMPUTATION OF NET PRESENT VALUE, INTERNAL RATE OF RETURN AND RISK

Refer to financial theory, risk theory and related documents for the calculation of discounted cash flow (DCF), net present value (NPV), internal rate of return (IRR), risk-adjustment and related metrics. Appendix B provides a brief introduction to discount rates for the information of technical analysts who do not have financial training.

3.2.2 ECONOMIC EVALUATION AND FINANCIAL MODELLING

Preferably the evaluation of the economics of an investment is kept separate from the modelling of its financing:

- Evaluate the economics of the underlying cash flows without financing as the first step. Understand the viability of the underlying investment. This is economic evaluation.
- Consider ways of financing the investment, in financial modelling, as the second step. This is financial modelling.
- If financing is combined with the economic evaluation then the discount rate will need to be adjusted.

3.2.3 MODELLING, VALUATION AND EVALUATION

- Evaluation is a three-tier process. Modelling is creating the working tool at the bottom; valuations are the outcomes of using the model to test various possibilities and scenarios, while evaluation is the highest level process of understanding the best outcome for the business or organisation. Evaluation is the process of considering the economic worth of an activity. It should investigate all inputs, computations, outputs, cases and alternatives.
- Valuation is an outcome of the evaluation process where a single value or a range of values is/are produced under set/sets of conditions.
- The numerous assumptions involved can lead to varying views as to the value of a project, organisation, etc when applying the DCF technique. This tends to lend weight to experience being of particular importance.
- Valuation exercises are more accurate when ranking projects, etc on a relative basis. That is, under a common set of assumptions, one can identify which project, within a suite of projects, will provide the greatest value.
- Valuations are undertaken in an absolute sense when an absolute value is attributed to the project, which is not ranked relative to other options. Values are always based on future estimates and hence a level of uncertainty is inherent.
- When undertaking valuations on an absolute basis a range of outcomes should be determined.

3.2.4 STAND-ALONE OR INCREMENTAL VALUE

The overall approach to evaluation may be incremental value or total value:

- An existing organisation or activity is usually valued in absolute terms.
- An investment is usually valued as its incremental economic impact – the value of proceeding minus the value of not proceeding.
- Incremental evaluations should incorporate all impacts of a change. It may be easier and less error-prone to model the whole organisation with and without the change, rather than trying to isolate the incremental impacts only.
- In all cases the evaluation should consider whether there are alternatives, ie staying with the status quo or whether it may improve its base activity with a smaller investment.
- Synergies brought by combining operations will usually require a stand-alone evaluation.

3.2.5 STAND-ALONE, SYNERGIES, USING TAX LOSSES

Normally the assessment is to be of the entity on a stand-alone basis. If there is a special reason for cross-subsidy or cross-penalty then its quantum, importance and likelihood must be clearly described:

- Typical benefits/penalties from outside may include the realisation of pre-existing tax losses (if usable), synergies from combining activities and market position.

- This should not be included if the benefit/penalty is likely to be realised in the normal course of business without this activity/investment.
- The valuation should clearly differentiate between the value of the entity on its own (stand-alone) and the value of any special benefits/penalties from outside.
- The conditions for receiving benefits/penalties from outside should be outlined. Other ways of realising these benefits/penalties should be outlined.

3.2.6 GEARING (DEBT)

Normally the economic assessment is of the underlying economics before the introduction of any debt. If for some reason debt must be considered the discount rate must be adjusted and the quantum, risks and importance of the debt described.

In some cases, cash flow analysis is undertaken in nominal terms and inclusive of debt. This is commonly required by financiers to determine if interest on debt can be covered without periods of default, if the debt can be repaid and what the equity value is via this particular approach:

- normally the cash flows should be unleveraged or ungeared, ie before the use of any debt and, hence, without interest costs of debt and their tax deductions
- according to financial theory the discount rate is adjusted if debt is introduced
- faulty evaluations can make debt appear to improve the NPV.

3.2.7 EXPECTED VALUES AND RESULTS

- There is an element of subjectivity when estimating what is expected in the future, even if basing estimates on historical data, as past occurrences will not necessarily represent what will happen in the future.
- Certain variables will be more subjective than others: future commodity prices are generally unknown and can vary widely from the forecast, whereas future concentrator recovery rates for an operating plant might change but are more likely to be understood very well.
- The impact of a change to a parameter should be anticipated and checked against the result from the economic model. Unexpected effects should be reconciled.

3.2.8 ALTERNATIVES

The evaluation should consider all reasonable alternative activities/investments that are possible:

- Although one activity/investment is proposed there may be alternative activities/investments that achieve the desired outcome.
- The 'do nothing' case usually is an alternative, and may be called the base case. If the investment is not made, how would this base case be optimised?

3.2.9 RANGES AND LIKELIHOODS / SENSITIVITY ANALYSIS

Within each activity/investment the evaluation should consider the range of possible occurrences and evaluate the spread and likelihoods:

- Unless only one result is possible the evaluation should consider the likely range of inputs, computations and results rather than reporting a single case.
- There are various methods of considering ranges and likelihoods.

- One method considers a series of discrete feasible cases from low to high and probability weights them.
- Another method uses software to generate a distribution of outcomes. If this method is used, the parameters included and excluded should be disclosed.
- Key inputs should be prioritised and varied by the amounts by which they can be expected to vary. Usually these are done at reasonable highs and lows and again at near extreme highs and lows. Sometimes these are best tested in clusters of parameters but usually it is testing one parameter at a time. Sensitivity testing of ± 10 per cent and ± 25 per cent, etc now is regarded as having low value. It is important to recognise that this type of valuation typically assumes only one variable changes at a time, and the same underlying physical mining, treatment and sales plan is maintained for all variations considered. It does not take any account of how decisions, and hence the plans, would change in response to real changes in the inputs being flexed in the evaluation. For example, if the price is increased then the mine schedule probably should be reoptimised.

3.2.10 INPUT DATA QUALITY ASSESSMENT

If distributions or likely ranges are not available for various input data items, the following ranking scheme is one of many that may be useful:

- A separate column beside the input numbers may be presented to indicate the reliability of various input data items. The score of input data would be put as a number, eg from 1 to 3. For example, if the input is from a reliable supplier's quote it may score 1, if from open literature and verified, 2, and if an educated guess with large uncertainty, score 3.
- Total scores may be averaged. Then uncertainty can be low, medium or high depending on the class of score the data received. If the input data quality scored less than 2, uncertainty is low, if above 2 but below 4, medium and if above 4 is high, etc.
- In some situations the data quality may be required to score a '1' and in other situations, eg preliminary technical economic evaluation or where the process is conceptual, a higher uncertainty is acceptable.
- Others may choose to describe the level of accuracy as conceptual (eg ± 30 per cent), prefeasibility (eg ± 20 per cent) or feasibility (eg ± 10 per cent) and reflect accuracy in context of some weighted average.

3.2.11 REAL AND NOMINAL

A real model expresses a time series of cash flows in which the effect of inflation is excluded. The advantage of presenting data in real terms is that evaluations are more easily understood and audited. Economic models of whole-of-life projects and strategic plans are normally expressed in real terms.

A nominal model expresses a time series of cash flows in the actual dollars of the period: that is with inflation included. Budgets, short-term forecasts and commodity price forecasts are usually expressed in nominal dollars.

Care must be taken to ensure that the real and nominal information is not mixed and that each is clearly identified in the units column. A real currency unit should be labelled with its year:

- Some practitioners use vertical font for real terms and italics for nominal terms data.
- If applying the correct real and nominal discount rates to the real and nominal cash flows, the NPV will be the same by either method and IRRs from real and nominal cash flows

will differ only by the inflation rate. Care must be taken to apply a nominal discount rate to nominal cash flows and a real discount rate to real cash flows.

- For real terms evaluations the effect of inflation over the years is removed. Prices may increase/decrease in real terms because of production efficiencies, market demand/supply, foreign exchange movements and other non-inflation impacts.
- If working in real terms, there are two ways of handling tax depreciation and other items normally calculated in nominal terms
 - model these items in nominal terms and convert back into real terms, or
 - model these items in real terms and erode their value by inflation.

3.2.12 LIFE OF THE EVALUATION

Normally an evaluation is done for the remaining economic life from the present day to the end, including closure costs and legacies. If there is a special situation and only part of the economic life is considered the parts of the life excluded and estimates of their impact on value should be clearly described:

- The NPV can be mathematically calculated at any point in the life of a cash flow. For practical purposes a convenient date in the recent past or the near future (as a guide, within six months) is used with any significant cash flows in the intervening period clearly noted.
- Many companies specify a valuation date to be applied for consistency in all evaluations conducted.
- The remaining NPV at various times in the future (ie the NPV that would be determined by analysts at that time, assuming the project and the world economy proceed as predicted now) may also be a useful measure for comparing options in a long-life project.
- The end date should be a sensible time in the future when significant cash flows and liabilities are expected to finish.
- Estimates of closure costs and legacies, such as ongoing remediation may be substantial and can have a significant impact on NPV. A broad assumption that salvage will pay for closure costs and legacies is not usually valid.
- Sunk costs should be excluded from an NPV calculation as they do not represent a future cash flow. However, the written-down value (for tax purposes) of previously-purchased assets is relevant to future tax calculations and may be required.

3.2.13 AFTER TAX

Normally evaluations are after all taxes. If there are special circumstances where pre-tax evaluation is appropriate the circumstances should be explained:

- Taxes other than company income tax and international withholding taxes are normally included in the capital costs, operating costs and revenue.
- Normally, company income tax and mineral royalties should be included as a discrete block of computations in the evaluation.
- Normally, the evaluation is unleveraged and so company income tax is before the introduction of debt-related cash flows.
- Where the valuation is of an entity in another country the impact of international taxes, such as withholding tax, should be estimated.
- Where international taxes are not yet adequately defined, a statement describing the range of possibilities, along with the impacts on value, should be included.

- Evaluations may be conducted at mine site level to select between various operating strategies. These might be conducted on a pre-tax basis where tax is the same for all or is relatively unimportant. This is usually satisfactory for options with similar levels of capital intensity, but may give misleading results if comparisons are between low capital / high operating cost and high capital / low operating cost options. It is advisable for the technical economic evaluator to at least include a simple tax calculation to ensure that the pre- and post-tax evaluations are not suggesting different strategies.

3.2.14 RISK AND UNCERTAINTY

The inclusion or exclusion of risk in an evaluation is of high importance:

- A complete economic evaluation requires an understanding of the impact of risk and uncertainty on the final outcome. Decisions should take into account the robustness in the expected performance. There are many ways of modelling risk and uncertainty in economic evaluations: these methods are touched on but not comprehensively covered in this document. To adequately evaluate risk and uncertainty, economic evaluations should include one or more of the following features
 - Sensitivity analysis – the impact of changing one variable at a time. These results have severe limitations because they typically neglect the flow-on impacts of that change on the plan.
 - Scenario analysis – these are superior because they consider the dynamics of interrelated changes.
 - Monte Carlo simulation – independent or correlated variables are changed multiple times to reflect the probability distributions of their values, producing a probability distribution of the outcomes. These should be used with extreme caution to ensure all key parameters are varying, with appropriate correlations between them and not just with selected key parameters that are convenient to define, such as price, capital expenditure (capex) and operational expenditure (opex).
 - Option analysis (see section 3.4.1).
 - Value at risk (see section 3.4.2).
- The evaluation should clearly describe if risk was excluded and describe the risk context.
- The evaluation report should clearly describe the process by which risk was included and any recognised deficiencies.
- The risks may be introduced into the component cash streams during computations, or using expert knowledge, into the case as a whole by way of the discount rate
 - If introduced into the component cash streams a risk can be reflected by adjusting the input related to the risk, eg metallurgical recovery rate – lower recovery, lower valuation. Care must be exercised if worst case values are used for a number of variables: the probability of all the worst case scenarios occurring concurrently is generally very low. A probabilistic analysis is preferable if suitable distributions can be developed for all key input parameters.
 - If introduced by the discount rate then a risk premium can be added to increase the discount rate and generate a lower valuation. This requires expert knowledge and is discussed further in Appendix B.
- Some project managers will identify risks that are considered partially or totally avoidable. The assessors of such technical and non-technical risks will rely on their professional opinion and precedent to weigh up the validity of such assumptions.

This does not guarantee the risks will be addressed as envisaged and the analyst, in conjunction with the project members and leader, will have to determine if these risks should be considered in the quantitative component of evaluation via the approaches described above or via an exercise in likelihood/sensitivity analysis.

- Evaluation specialists should not accept a methodology of incorporating risk without understanding it. Specialists should not be baffled by persons who appear to be experts persuading them to adopt a method that appears too complex to understand. If required to complete the exercise then the specialist should make the situation clear to team leaders and decision makers.

3.2.15 MATERIALITY

The evaluation should match the quality (detail, precision, complexity) of each computation with its impact on the result:

- The evaluation should give most attention to the inputs and computations that have the greatest impact on value. Extra columns totalling cash flow and showing the contribution to NPV may help identify materiality.
- The evaluation should aim to reduce the complexity and detail of less important computations where this will not significantly reduce the validity or accuracy of the result.
- The focus should be on the key drivers of value. It avoids computations that are overly detailed in areas with minor impact on the key results.
- Usually, the computation of revenue has the greatest impact on value, followed by operating costs and/or capital costs, and the least impact comes from taxes.
- Normally the greatest focus is on the generation of revenue from the resource in the ground through production to sales volumes and product quality, and to price and foreign exchange rates.
- Operating costs in preliminary evaluations may be simple fixed and variable costs, whereas in later-stage evaluations they may be detailed fixed and variable costs for each cost element, such as labour, fuel, materials, etc. The variable costs at each stage in a process flow sheet should relate to the quantities being processed at each stage. They should not be related to the quantities of ore tonnes or final product.
- Capital costs in preliminary evaluations may be coarse estimates, whereas in later-stage evaluations they may be detailed estimates.
- In many evaluations taxes and working stock calculations can be greatly simplified without significant loss of accuracy.

3.2.16 EVALUATION FRAMEWORK

An easy-to-follow framework is to use the four cash streams of production/revenue, capital costs, operating costs and taxes leading to net cash flow and value measures such as NPV.

Reducing the evaluation to four cash streams makes computations, audit and understanding rapid:

- cash stream 1 = revenue = sales $\times$ price $\pm$ debtors
- cash stream 2 = capital (cash spent, not commitments)
- cash stream 3 = operating costs = consumptions $\times$ costs (including related taxes) $\pm$ working capital

- cash stream 4 = taxes = company income tax + government royalties (if not in operating costs) ± adjustments for cash payment dates.

International organisations usually should be valued at three levels:

4. the stand-alone operation/organisation in 100 per cent terms regardless of ownership to determine the health of the underlying organisation
5. the values to the various owners of their shares of the organisation, in country but after special deals and taxes
6. the value to the various owners of their shares after repatriating cash flows to their home countries and paying top-up taxes there.

3.3 Process

3.3.1 PRODUCT PRICES, TREATMENT AND REFINING CHARGES AND FOREIGN EXCHANGE FORECASTS

Usually forecasts of product prices and foreign exchange (forex) are amongst the most important assumptions for calculating an NPV. They not only partially determine revenue each year but they determine how much of the mineral deposit is economic. The following activities are recommended:

- Explain the sources of forecasts and whether they were modified.
- Graph the key price(s) and foreign exchange in historical terms and the low, mid and high price(s) assumed into the future for the life of project.
- Usually the computations of revenue have greatest impact on value. Ironically computations of revenue in some commodities are relatively simple once production and sales are computed.
- Where the computation of price is complex – such as the treatment terms, refining charges and associated charges for metal concentrates – a top-down approach may be a superior method
 - For example, the history of treatment charges (TC) and refining charges (RC) is converted into graphs of how the value of each contained metal in the concentrate has been shared on a percentage basis, eg 67 per cent to mines and 33 per cent to smelters – and this is forecast rather than using TCs and RCs. However, the split may vary with price and a more complex pricing model may be required.
- There are numerous approaches used for dealing with currency mixes and real and nominal terms within the economic evaluation. One approach is described in the section below on operating costs.

3.3.2 SALES – VOLUMES, QUALITIES, WORKING STOCKS/CAPITAL

Together with price and foreign exchange forecasts the sales volumes are important assumptions. It is recommended that the model:

- Outline market volume and quality assumptions.
- Outline the forecast impact of these sales on the market.
- Outline any unusual logistics.
- Working capital in debtors can be approximated, eg four weeks/52 weeks × sales revenue for debtors (same with costs for creditors). Revenue lags for base metals concentrates may be estimated from actual or typical sales terms.

- Working stocks of sales product should be approximated in the synthesis of production where they are significant.
- Establishing working stocks may be a significant drain on cash at project start-up and during ramp-up. There may be a significant lag between production ramp-up and product despatches and receipt of revenue until the organisation reaches steady state.
- Movements in working capital should be included in the computation of cash stream 1: revenue. See also the discussion of working capital related to costs in Sections 3.3.4 and 3.3.5.
- Simple stocks calculation methods can include
 - maintaining a specified stockpile size at the end of each time period, drawn down at the end of the life
 - applying a time lag between production and sales dates.

3.3.3 PRODUCTION – VOLUMES, HEAD GRADES, RECOVERIES, PRODUCT GRADE, DELIVERY

The economic evaluation may synthesise the production process or use outputs from detailed computations and syntheses. It is recommended that the model:

- Outline the methods used to estimate production, including how life-of-mine (LOM) figures are determined, which may include mine and plant availabilities, mining volumes, mining recovery and dilution, head grade, process recoveries and product specifications for economic metals and key deleterious constituents.
- Describe the methods by which time frame of the life of the entity was estimated, including construction time, ramp-up, operational life and closure.
- Outline the various broad production cases considered.
- Disclose whether the Resource and Reserve figures used in the model are reported in accordance with the Australasian Joint Ore Reserves Committee Code (JORC), ie if the figures are existing Resources and Reserves, if the evaluation will be used to support publication of Reserve categories, or if they are estimates that are not JORC-compliant (note that the JORC Code is for public reporting of Resources and Reserves. Internal evaluations can do whatever is reasonable for the purposes of the evaluations, though JORC Code categories of Resources and Reserves may be important input information, even if results are not to be made public).

3.3.4 CAPITAL COSTS

Estimates of capital costs can vary from high-level estimates to comprehensive estimates, including contingencies and allowances. It is recommended that the model:

- Outline the method used to estimate capital costs, including indirect costs, contingencies, allowances, etc. Preferably these estimates would be based on studies that employ an industry-accepted methodology and supported by appropriate documentation. The accuracy and confidence in the estimate is expected to increase as the project progresses through the conceptual, scoping, prefeasibility, feasibility and detailed engineering study stages.
- Outline the method (such as quotations, material take-offs, factors, benchmarking, etc) used to estimate capital costs, including indirect costs, contingencies, allowances, construction costs, engineering, procurement, and construction management (EPCM), freight costs, local duties, etc.
- Outline the key construction costs and time to commissioning assumptions.

- It is not important if a particular item is classified as an operating cost or as a capital cost in the evaluation for determining pre-tax cash flows. It is important that each item is correctly treated in the tax and in any accounting computations. Correct classification is essential for determining depreciation and profit or taxable income for the modelling of both taxation and financial accounting. It should be noted that certain items may be capitalised for one set of calculations and expensed for the other, or capitalised but depreciated by different methods and/or rates for tax and financial accounting calculations.
- Outline the range of estimates of capital cost. The differences in NPV across the range of capital costs should be computed and understood by decision makers.
- Consider the timing differences between capital construction and payment.
- Outline details of any bond (eg environmental) that may be required, distinguishing between non-cash accounting provisions and cash flows.
- Ongoing or sustaining capital, which maintains the capabilities acquired by the initial project, should be calculated from its drivers. It may be a proportion of the initial capital expenditure, or based on history in a more mature operation. Although often expressed as an annual cost, it may be more appropriate to express some components on a per-tonne basis if changes in production rates are to be modelled.
- Working capital may significantly impact on early cash flows. Key items are typically
 - first fill of consumables in the operation – eg grinding media, tyres, etc
 - major critical spare parts
 - initial stocking of other warehouse consumables
 - operating costs incurred before initial revenue is received.

3.3.5 OPERATING COSTS

Estimates of operating costs can vary from broad approximations to detailed estimates. The principles discussed in the capital cost section on accuracy and data sources generally apply to operating cost. It is recommended that the model:

- Outline the method (such as quotations, material take-offs, factors, benchmarking, etc) used to estimate operating costs, including fixed and variable costs, social and environmental costs, contingencies, etc.
- Categorise costs by function, eg mining, milling, etc or by cost element, eg labour, fuel, consumables, power, maintenance, materials, etc. Cost structures that are built up by both function and cost element along with fixed and variable components are considered to represent the highest order of detail. It should be noted that when accessing historical accounts, functional and cost element information is generally available, whilst the analyst will have to form a view on what costs are fixed and what costs are variable as accounting systems rarely categorise on this basis.
- Categorisation of costs as fixed or variable will depend on the time frame of the evaluation. What is fixed in the short term may be variable in the long term.
- As a general principle, variable costs should be applied to each physical activity for which quantities will vary relative to the key activity quantities as a result of changes in inputs that may be flexed, or naturally as a result of changes in the resource being mined or the tonnage treated. However, materiality effects and the required level of accuracy of the study should also be taken into account – changes in the ratios of the physical quantities may be small enough to obviate the need for the more complex cost model, and a simple ‘fixed plus variable per tonne of ore’ model may be adequate.

- Outline the commissioning and ramp-up assumptions.
- Working stocks are included in the synthesis of production and are approximated where there is insignificant impact on value.
- Private royalties are included as an operating cost but government royalties can be included either as an operating cost or as a tax, depending on custom. However, the procedure adopted in the evaluation should be defined.
- For leased equipment, note if the lease is an operating lease or a financial lease.
- As per the classification of capital costs, it is not important if a particular item is classified as an operating cost or as a capital cost in the evaluation for determining pre-tax cash flows. However, correct classification is essential for determining depreciation and profit or taxable income for the modelling of both taxation and financial accounting effects. It should be noted that certain items may be capitalised for one set of calculations and expensed for the other, or capitalised but depreciated by different methods and/or rates for tax and financial accounting calculations. This will impact on correct calculation of post-tax cash flows.
- The operating costs component of working capital may be simply modelled by
 - maintaining a specified inventory at the start of each time period, drawn down at the end of the life, but allowing for spoilage and obsolescence, or
 - applying a lead time between production and spending.
- Outline the range of estimates of operating cost. The differences in NPV across the range of operating costs should be computed and understood by decision makers.
- There are numerous schools of thought when dealing with operating costs in various currencies and a mixture of real and nominal terms – one approach that can be applied to overseas operations is as follows
 - initially model costs in the currency in which they are incurred
 - it may be necessary to separate different currencies – eg expatriate and local labour costs, consumables sourced from various locations, etc
 - identify the costs that are quoted in one currency but are actually incurred in another – eg petroleum products
 - derive as real (or perhaps more accurately, uninflated) costs in the currency in which incurred, for the physical quantities scheduled
 - note the age of various data items and inflate/deflate to a common point in time if appropriate
 - apply inflation for original currency, appropriate to each cash flow item – produces nominal cash flows in those currencies
 - convert to the currency of the country taxing the operating entity (usually the country where the operation is located), using nominal exchange rates
 - calculate depreciation for tax purposes, and hence taxable profit and tax, and hence net cash flow in the currency of the taxing country
 - convert to the reporting currency, using nominal exchange rates (additional taxes may need to be calculated in this currency)
 - deflate to real money amounts using the appropriate deflator for the reporting currency
 - discount using real after-tax discount rate.

3.3.6 CLOSURE COSTS

Estimates of closure costs can vary from broad approximations to detailed estimates. It is not adequate to assume that closure costs will be offset by the proceeds of salvage. It is recommended that the model:

- Outline the method used to estimate closure costs and ongoing activities. Describe if indirect costs, contingencies, allowances, etc are included.
- If the evaluations will vary parameters that will change the mine life, it may be necessary to express rehabilitation, redundancy costs, salvage and scrap values as functions of the closure date.

3.3.7 TAXES (DIRECT COMPANY LEVEL TAXES)

In an economic evaluation, taxes are not usually computed to the precision of official income tax returns, but usually are more simplified so that the results match the precision and impact of other key computations:

- Taxes include company income tax, special company taxes, capital gains, carbon taxes, resource rent taxes, withholding taxes, international taxes and government royalties. Indirect taxes are usually included in capital and operating costs.
- Outline assumptions regarding each tax. Describe any special tax issues, eg if withholding taxes can be credited in the tax regime where profits are repatriated.
- Outline any tax benefits or penalties that are specific to this investment, such as pre-existing losses, or cross subsidy special government taxation arrangements. Describe the importance to value.
- Income tax may be approximated where the impact is not material. A few rows of algorithms may substitute for many rows of longhand depreciation or other calculations. If the evaluation model is constructed to be flexible to permit the evaluation of a large number of options and scenarios, it is essential that tax calculations are also flexible within the model.
- If capital costs are computed in real terms then in the evaluation model the tax deductions for depreciation and amortisation should be eroded by inflation – unless the impact of inflation is not significant. Otherwise, the tax depreciation is computed in nominal terms and converted back into real terms.
- As discussed in the section on operating costs, government royalties can be included in operating costs or in tax, depending on custom.

3.3.8 DISCOUNT RATE AND NET PRESENT VALUE

Technical economic analysts will rarely have to derive the discount rate to be used. Doing this is an expert task not normally within the expertise of such analysts. The discount rate is computed according to financial theory and is typically specified by the organisation commissioning the evaluation. Notes on the derivation of discount rates are included in Appendix B as background information for technical evaluators without financial training. The important thing for the analyst is to ensure that the discount rate used and the cash flows to which it is applied are consistent:

- Historically in the mining industry there have been various conflicting approaches to computing discount rate. These include
 - Is the discount rate for the organisation or for the industry sector being evaluated?

- How is debt included?
- Is the evaluation before or after tax?
- In an evaluation model the net cash flow can be converted to NPV using several methods
 - One method is to use a few rows of easy-to-follow computations (longhand) rather than using NPV functions or software. Longhand computations are more readily understood and checked for base date and discount factor for the first periods.
 - The other method is to use spreadsheet functions. However, these are often used incorrectly, and care is required with regard to the timing of cash flows.
- The discount rate must match the cash flow, ie real or nominal terms, and before or after tax.
- Using the appropriate discount rate with a cash flow, whether in real or nominal terms, should give the same NPV. Before-tax NPV and after-tax NPV can differ.
- Cash flows from operations occur throughout the year, not necessarily at the start or end of a year. To reflect this, discounting from the midpoint of each period is recommended for an absolute valuation. For comparative valuations, this is less important, but consistency of approach for all cases is essential.

3.3.9 AUDITING

Auditing is an essential component of the evaluation process. It best occurs progressively during the evaluation process, and must be undertaken before any results are released. The status of the audit should be progressively recorded in the 'Introduction' to every evaluation model:

- Step 1 – periodic self-audits of the evaluation model as it is developed.
- Step 2 – audits of the parts of the evaluation by the experts in each of the parts.
- Step 3 – a thorough audit of the final evaluation model by parties external to the evaluation project. One party may audit the mechanics of computations while other specialists audit the validity of inputs and outputs.

Additional tips on auditing:

- Check the graphs for anomalies, inconsistencies and trends that look incorrect.
- Use software that analyses spreadsheets to find errors.
- Include self-checks for totals and subtotals throughout the model. Do these totals match the input data and external documents?
- Starting at the NPV work back up each of the cash streams to the inputs.
- Check a column away from the first column of computations in case a change has been made but accidentally not copied across the rows.
- Copy the algorithm in the first column of computations across to the end of life and see if the results change (but be aware of rows where the first column may legitimately be different from the others).
- Check the outputs of large evaluations by creating a stand-alone summary model of only a few rows.
- When auditing, it can be useful to create a new sheet at the front of the workbook with
 - all auditing notes listed
 - a list of items to be checked or corrected using a priority colour-code system, noting high-, medium- and low-ranked items (using red, yellow and green cell colouring)
 - links to the sections of the model to which the auditing notes apply.

3.3.10 GRAPHS

Graphs are recommended as:

- a quick check for errors in input data, computations and outputs
- a fast way for others to understand the evaluation.

Adequate time should be allowed for the evaluation model to graph all key inputs and key outputs as checks on errors and for rapid understanding of the entity. These should include cash flows, NPV, prices, sales volumes, production, grades, saleable product, revenue, capital costs (construction and ongoing), operating costs and taxes.

3.3.11 HELICOPTER VIEW

The evaluation process should be conducted with regular pauses to understand how the entity looks from a helicopter view. Results and graphs should be viewed and discussed after important stages in the development of the evaluation.

3.3.12 WHAT TO AVOID

- Over-complexity.
- Black box spreadsheet functions.
- Black box models and standard template models that claim to cover all evaluations.
- Links to other workbooks: these are dangerous because the other model may be altered without the change being recognised. If used the whole row/column with titles and labels is referenced across so covert changes can be seen.
- Macros that perform calculations: these cannot be readily followed visually, nor audited, and generally are not trusted.
- Hidden rows, columns or worksheets: the 'Data / Group' facility is satisfactory because it marks the collapsed data.
- Spreadsheet functions that have a history of misuse: these are difficult to audit, whereas longhand computations can be followed easily and visually.

3.4 Alternative evaluation and assessment methodologies

Although the DCF approach is the preferred methodology used in the mining industry, numerous other methodologies are available and are increasingly being used on a more regular basis. During the course of developing these Guidelines the topic of alternative methodologies was raised and discussed. It was deemed prudent to highlight the existence and continuing emergence of these alternative methodologies and to discuss a couple in brief, namely real options valuation (ROV) and value at risk (VaR). The AusIMM does not in any way suggest that these methodologies be used in assessing mineral projects, but rather that members keep in mind that alternative tools are available and are being increasingly accepted in conjunction with the traditional DCF approach.

3.4.1 REAL OPTIONS VALUATION

What is real options valuation?

The real options valuation (ROV) technique was derived from the Black and Scholes financial option-pricing model developed in 1973. The sequence and timing of decisions can be modelled using ROV, thus providing a method that values project flexibility.

When real options valuation should be applied?

Real options valuation is suited to projects with inherent future uncertainties. For a project with little or no uncertainty, ROV can be used; however, it will yield the same result as a traditional DCF valuation.

ROV should be used when differing business strategies exist to determine the value of each strategy. Additionally, it can determine at which time a strategy should be acted upon.

Benefits and drawbacks of the method

ROV can accurately value decisions under an uncertain future. However, the accuracy of the valuation depends significantly on the assumptions used to carry out the valuation.

Computing time is dependent of the number of uncertain parameters incorporated into the valuation, thus as ROV complexity increases so too does computing time. To minimise computation time key parameters (ie commodity price, recovery and mining rate) need only be included. Computer programs, such as decision programming language (DPL), allow a ROV to be computed in under a minute with as many as ten uncertain input parameters.

One of the greatest benefits of using a real options process is that it can change a decision-maker's way of thinking. The real option way of thinking may see the early abandonment of an uneconomic project as a success. It places importance on the ability to modify a plan rather than to adhere to it and it favours investments that are robust to uncertainty rather than dependent on it.

3.4.2 VALUE AT RISK (VAR)

What is value at risk?

Value at risk (VaR) is used in finance for measuring and managing risk. When used in portfolio management it is commonly expressed as a probability of making a loss or return below a certain dollar value over a specific time period, eg an asset portfolio with a one-week five per cent VaR of \$10 M has a five per cent chance of decreasing in value by more than \$10 M over the week.

When should value at risk be applied?

The VaR method provides an estimated distribution of outcomes. It also allows the management of risk by providing a feel for exposure on the downside and hence provides an opportunity to tailor risk exposure.

Benefits and drawbacks of the method

Application of VaR in the mining industry involves the identification of risks and their interdependencies at all levels. This involves a comprehensive stage of quantifying and considering all the risks, reducing the chance of oversights that may occur when using alternative methods.

The identification of risks that are material, understanding their interdependencies, along with the quantification and modelling of probability curves is an involved process that requires gathering a considerable amount of information.

The concept that a statistical approach can be applied for understanding the distribution of value outcomes and that then striking a VaR is applicable to numerous markets holds true. In financial markets, the method is used to make decisions for investing in various

markets, each with their respective levels of risk, liquidity and volatility. Mining assets demonstrate their own peculiar characteristics around liquidity and volatility, suggesting that concepts inherent in VaR will be used for making longer-term decisions concerning existing and proposed projects rather than, as it is currently used in financial markets, for shorter-term portfolio management.

APPENDIX A – WORKED EXAMPLE

Readers are directed to the Microsoft Excel file included with this PDF. The example is illustrative, and is not intended to be definitive, of how to structure a model. The analyst should always consider that, when structuring a model and summary page, it is important to consider the level of detail at which the exercise is to be undertaken, the audience it is intended for and the information normally expected to be conveyed.

The included example was made available to AusIMM members and participants at the AusIMM Project Evaluation 2012 conference in Melbourne in May 2012.

APPENDIX B – INTRODUCTION TO DISCOUNT RATES

This appendix is intended to be a brief introduction to the theory underlying the specification of discount rates. It is assumed that the reader understands the basic principles of the time-value-of-money and the mechanics of conducting a discounted cash flow (DCF) analysis to derive a net present value (NPV): these are not discussed here. Rather, the purpose is to provide background information to the technical economic analyst who may not have formal training in the field, so that he/she understands what the discount rate is intended to do, how it is likely to have been derived and most importantly to ensure that the discount rate used and the cash flows to which it is applied are consistent.

It should be noted that the discussion is for typical DCF evaluations. However, many of the principles apply, with variations, to alternative valuation methodologies such as real options valuation (ROV). The discussion is under several subheadings, as follows:

- *Weighted average cost of capital (WACC)* – the discount rate typically used in many companies.
- *The capital asset pricing model (CAPM)* – typically used to determine the rate of return required by shareholders (or equity holders) in an organisation.
- *Cashflows – real or nominal, before or after tax* – any of the four combinations of these parameters could be derived and different discount rates will be required in each case. Cash flows can also be expressed as before and after debt, ie excluding or including interest costs that will apply. Cash flows that are after the deduction of interest costs are typically referred to as geared. In our coverage of discount rate we will, as is typical in the resources industry, refer to analysis on an ungeared basis, before considering the financing cash flows, hence the four possible discount rates rather than the eight that are possible if also considering geared cash flow analysis.
- *Additions to the weighted average cost of capital* – there are two generally accepted approaches for reflecting risk in DCF valuations – via the cash flows or via the discount rate. That is, either the cash flow is reduced or the discount is increased and this results in

a lower valuation. In effect, the higher the risk, then the greater the return sought. Many companies add risk premiums to the weighted average cost of capital to account for risks of dealing with different commodities or different countries.

Weighted average cost of capital

To specify a discount rate, it is essential to ask what it is intended to achieve. Clearly this will be the same as what it is intended that the project should achieve. The underlying purpose of any project will typically be at least to return to the investors their capital plus a required rate of return. The mechanics of a typical DCF calculation are such that, if we discount an organisation's cash flow at the organisation's WACC and get an NPV of zero, we have repaid the capital and delivered the required return. Any positive NPV is the value added by the project over and above the repayment of capital and delivery of the required return.

Any venture will be funded by debt, equity or a mix of the two. The weighted average cost of capital is the cost to the organisation of its total debt and equity funding. It is derived from the following formula:

$$\text{WACC} = r_E E/V + r_D (1-t) D/V$$

where:

r_E = return required on equity, or cost of equity

r_D = return required on debt, or cost of debt

E = market value of equity

D = market value of debt

V = $E + D$

t = tax rate

When discounting a cash flow to calculate an NPV it is important to use a discount rate that is in the same terms as the cash flow. The WACC is applied to ungeared after-tax cash flows and so has a component of cost of debt (or interest) and cost of equity to suit the fact that the cash flow is available for servicing debt and equity. The cost of debt is paid before tax. Hence, its after-tax cost is $r_D(1-t)$. The $1-t$ factor is often referred to as the tax shield. Equity holders are paid from retained earnings and the physical cash payment from cash flows after tax. Hence, the cost of equity is already post-tax and does not need to be adjusted for the tax shield – it does not apply.

The variables E and D are sometimes determined from the organisation's publicly reported balance sheet. The balance sheet figure may be a good representation of the market value for debt, whilst the market value of equity for publicly listed entities is better represented by the market capitalisation of the organisation.

The cost of debt, r_D , is typically relatively easy to determine from the dollar amount and interest rate of each source of debt funding, typically described in detail in the notes to the annual accounts in the organisation's annual report. One should also remember to check for any new or retired debt facilities reported by the organisation since the last reported balance sheet.

The required return on equity capital, r_E , can be derived by various methods: this discussion will cover the capital asset pricing model (CAPM) approach.

The capital asset pricing model (deriving the cost of equity)

Shareholders receive returns by two means, dividends and capital gains. The rate of return required by shareholders depends on the riskiness of the investment: if high risk, high expected returns are required; if low risk, low expected returns.

While accepting that in reality there is always some risk, there are investments that are considered risk-free, eg government bonds. These provide the risk-free return, r_F , and the ten-year government bond rate is most often used.

Investments spread over the total market would face the market risk and would be expected to provide the market return, r_M .

Investment portfolios can be built with a lower risk than the market, and these are expected to provide returns between the risk-free and market returns (ie greater than r_F and less than r_M). Similarly, investment portfolios can be built with a higher risk than the market, and these are expected to provide returns greater than r_M . Note that returns for investments in non-risk-free assets are average expectations in the long term, but are not guaranteed in any time frame, certainly not in the short term.

The CAPM relates shareholders' expected return (r_E) to risk by a linear function with a gradient of β , known as the beta factor, or simply the beta:

$$r_E = r_F + \beta (r_M - r_F)$$

where:

β is the ratio of volatility of company returns to volatility of market returns

The beta can be estimated as the change in share price (adjusted for dividends) divided by the change in the market accumulation index for the same time period. To determine an organisation's beta, a series of such data points is plotted over time and the gradient calculated. One could track share prices and market movements oneself, or buy information from specialist market research firms. In a mathematical sense, beta represents a measure of systematic (or non-diversifiable risk) in a portfolio of assets and is measured as the covariance of an asset's performance relative to the market divided by the variance in performance of the market.

Company betas are quoted on various market web pages, such as the major banks' share trading web sites and also published by the Australian Graduate School of Management. It is also important to remember that betas can be calculated over various periods (eg over 18 months, four years, etc) and there is more than one approach available (but often the ordinal least square method is used). An organisation's beta can also change over time.

By definition, the market $\beta = 1$ (if $\beta < 1$, the risk is lower than the market and if $\beta > 1$, higher), and $(r_M - r_F)$ is defined to be the market risk premium above the risk-free alternative. Figure A1.1 shows these relationships graphically: β is the gradient of the return versus risk line.

When identifying the beta, it is also of some importance to note the statistical correlation coefficient for the relationship identified: although a beta value may be determined, it may not be statistically significant. It should also be noted that some organisations are countercyclical and have negative betas: their returns move in the opposite direction to the overall market.

Accounting for inflation

Interest rates charged by finance providers and quoted in the organisation's annual report are used to specify numerically the dollar values of the repayments that will be made in the



FIG A1.1 - Capital asset pricing model (CAPM) – the cost of equity.

future, in the money of the time that the payments are made – these are therefore nominal rates. Similarly, the rates of return generated to derive r_E are typically based on reported prices over time, without any adjustment for the effects of inflation – these are also therefore nominal rates of return. The discount rate formulas quoted above are therefore nominal discount rates, which can only be correctly applied to nominal cash flows.

Inflation erodes the purchasing power of the interest and capital repaid over time. The real return is that which is over and above the inflation rate. If:

r_N = the nominal rate of return

r_i = the inflation rate

the real rate of return r_R is *not* given by:

$$(r_N - r_i),$$

but rather by the relationship (known as the Fisher equation):

$$1 + r_R = (1 + r_N) / (1 + r_i)$$

$$\text{ie: } r_R = [(1 + r_N) / (1 + r_i)] - 1$$

Discount rates and net present values – real and nominal, before and after tax

Combining the above, four possible discount rates can be derived and applied. The appropriate one to use will depend on what the cash flows to be discounted are:

Nominal, before tax $r_{NBT} = WACC / (1-t) = r_E \cdot E/V / (1-t) + r_D \cdot D/V$

Nominal, after tax $r_{NAT} = r_E \cdot E/V + r_D \cdot (1-t) \cdot D/V$

Real, before tax $r_{RBT} = [(1 + r_E \cdot E/V / (1-t) + r_D \cdot D/V) / (1 + r_i)] - 1$

Real, after tax $r_{RAT} = [(1 + r_E \cdot E/V + r_D \cdot (1-t) \cdot D/V) / (1 + r_i)] - 1$

The cost of equity, r_E , is an after-tax cost and so the before-tax discount rates have r_E grossed up to a pre-tax basis of $r_E / (1-t)$.

Before and after-tax NPVs can be different in a number of ways:

- the after-tax discount rate will be lower than the before-tax discount rate
- the points in times at which capital expenditure is incurred and when tax depreciation is realised are different
- an after-tax evaluation may include tax losses carried forward at the start of the project, it is quite possible for the after-tax NPV to be greater than the before-tax NPV (if a value is not attributed to the tax losses in the before-tax NPV calculation).

NPVs calculated from real and nominal cash flows should be the same if the correct discount rates are used. Mathematically, deflating nominal cash flows to real and applying the real discount rate does in two calculation steps what is done in one step by applying the nominal discount rate to nominal cash flows. Nominal-term calculations may use different inflators for various drivers and components of the cash flow. The effect of these will not necessarily average out to the general inflation rate that may be quoted, but if the overall deflation rate used in the analysis is also used in the Fisher equation for arriving at the real and nominal term discount rates, there should be no difference in NPVs.

Additions to discount rates

The discount rates as defined above by the WACC take account of investors' required returns only and the systematic risk – the undiversifiable risk of being in the market. They do not take account of the business risk of dealing with certain commodities or in certain parts of the world.

Many companies add a risk premium to the WACC to account for these factors – typically up to several percentage points for some commodities and for various countries or regions.

Risk premiums are rules of thumb that appear to have acquired legitimacy by consensus and long use. The committee developing these guidelines is not aware of any theoretical or evidentiary support for the process itself, nor for the values used for the risk premiums. The committee notes that, while using discount rates that include risk premiums may be satisfactory for comparing alternatives within a particular project, given its location and commodity, there are conceptual difficulties with comparing simple NPVs derived at different discount rates for projects with different commodities and/or in different countries. It is also perhaps worth noting that the organisation's beta already accounts for its current mix of commodities and countries where it is operating.

Monte Carlo simulation may be a more rigorous way to account for business risk, but only if reliable probability distributions for various data items are available. All key parameters including production rate and mineable resource need to be included: not just the easier-to-quantify parameters of operating costs, capital costs, grades and recoveries, etc. It is suggested without proof that the lowering of the NPV resulting from using a discount rate elevated by the use of a risk premium is perhaps a surrogate for identifying an NPV that has a higher probability (perhaps 90 per cent) of being bettered than the expected value that would be derived with no simulation of business risks and discounting at the WACC, which would typically have perhaps a 50 per cent probability of being achieved.

Proponents of other valuation methodologies would also suggest that the use of these would preclude the need to apply such risk premiums. This is discussed briefly in the section 'Discount rates in other valuation methodologies' in this appendix.

Financing cash flows

DCF analysis concerns itself with cash in and cash out, the timing of these cash flows and what the net value is in present terms under the desired rate of return set by the investors that provide equity and the lenders that provide debt. The parties providing equity and debt financing will require a return that is commensurate with the level of risk (perceived or real) and these rates determine the discount rate used in DCF analysis.

Although DCF analysis will identify the expected cash flows at the operational level it will not necessarily identify the timing and quantity of returns that the parties providing the equity and debt funding will receive. This is of obvious importance when considering that the parties providing finance will want to know when their payback will be received. Debt holders will require assurance that, under a range of possible scenarios, interest on the loan facility can be covered and that the debt will be paid back. Equity holders will want to understand when payback in the form of dividends will commence and what the return will be over the life of a project. Given that dividends are paid from retained earnings and debt repayment has seniority over equity payouts, the operation needs to be modelled financially. Ultimately it comes down to how providers of capital receive returns based on where they sit, eg geographically, in which currency, based on tax regimes that apply, how and when they can access cash returns or earnings, etc.

Publically listed corporations around the world have a statutory requirement to report their results under the respective accounting standards. Hence financial performance is assessed under these accounting measures. It is important to understand that:

- DCF provides a measure of value under an economic approach and tests if the cost of debt and equity is satisfied (etc) over the period of the cash flows
- financial analysis is a necessary step when gravitating towards the corporate and financial environments and will test, among other things, for the same over more discrete time periods (eg if interest payments can be covered each year).

The financing cash flows – capital repayments, interest, dividends and the tax effects of interest payments – are accounted for overall in the discount rates. They are therefore not included in the cash flows for economic evaluations determining project NPV, etc for a typical ungeared technical-economic evaluation.

However, a positive NPV does not imply that any particular pattern of cash flows is achievable. The financing cash flows may therefore need to be calculated outside the economic evaluation to confirm the ability of the operation to repay loans and meet debt coverage requirements, as may be required by financiers.

Calculation of an equity NPV calculation may also be requested, assuming specified debt funding for the project, to determine the return to shareholders. Debt draw-downs and repayments of capital and interest will then come into the analysis to derive an equity cash flow and the discount rate to be used will be the required return on equity. This is generally not recommended for the technical-economic evaluation: the project should stand on its own merits, and not depend on the financing arrangements for its viability.

One could also evaluate a project at the equity discount rate with zero debt funding to assess stand-alone viability of project. This would typically be a more conservative approach, as the required equity rate of return would usually be greater than the rate of return for debt.

Discount rates in other valuation methodologies

As noted in the introduction to this appendix, the preceding discussion is for typical analyses of total net project cash flow with discounting at the organisation's WACC, which

in essence treats the net cash flow by reference to the organisation's overall riskiness as perceived by the market. Risk premiums are used by some companies to account for the additional perceived risks of dealing with certain commodities and/or in certain countries.

Other valuation methodologies, such as modern asset pricing (MAP), Arbitrage pricing theory (APT) and real options valuation (ROV) approach the valuation problem from the point of view of identifying and dealing with various risks individually. Some of these methodologies are described in more detail in other sections of these guidelines, but for the sake of completeness in this discussion of discount rates, certain aspects are described here.

Some of these techniques account for the risk associated with individual components of the cash flow. Individual betas are derived for (for example) metal prices and various cost categories, such as labour, consumables, energy and so on. The techniques used to derive these betas will be similar to those described above for determining the shareholders' required rate of return. The betas thus derived are applied to the market premium (ie the difference between the market and risk-free rates of return) to derive discount rates relating only to the systematic or market risk of each cash flow item.

Each cash flow item is then discounted at its appropriate discount rate, the resulting cash flows then summed to obtain a total, which is then accounting for all risks. The only other item to then be accounted for is the time-value-of-money. The total risk-discounted cash flow is therefore then discounted at the risk-free rate of return to account for the effects of timing only.

The betas derived for each cash flow item will automatically account for the risks associated with the commodities and countries involved in the revenue and cost structure of the organisation and/or project. The result will be a dollar-denominated value, but since the discount rates used have no reference to the costs of debt and equity, there is no guarantee that a positive value implies that debt providers and equity holders can be repaid their investments and paid their required rates of return.

Concluding comments

It is rarely the task of the engineer or technical analyst to derive discount rates. They are usually specified by the corporate finance department.

Technical economic analysts should however be familiar with the assumptions underlying their derivation and ensure that the appropriate rate is applied depending on the cash flows generated: real or nominal, before or after tax.

In particular it should be noted that, while generating a positive NPV using the WACC as the discount rate implies that all providers of funding have received the repayment of their investments plus their required rates of return, this does not, as noted in the body of these guidelines, imply that any particular pattern of finance repayments can be made.

Different projects, companies and industries have different WACCs. There are numerous views on what the applicable WACC is when valuing an investment. The authors make no recommendations regarding these sometimes opposing views except to make readers aware they exist. However, it is recommended that some thought is given to such matters as: from what perspective the valuation is being undertaken, the size of the investment relative to the organisation, whether it is in an industry with different risks and typical WACCs from the organisation's investors' perceptions, how it will alter the cost of capital if the transaction proceeds and having a well-considered and justifiable position. Some of the (conflicting) views that may be encountered are:

- When valuing an investment, the marginal cost of capital is considered relevant. But the WACC can be used if weighted with the additional marginal cost. This ignores issues such as the marginal capital requirements being fully funded using debt and any effects on credit ratings and a possible increase in cost of debt. Many believe, if fully funded by debt, then the existing WACC at margin should be used. Over time, companies refinance and the marginal cost of capital will no longer apply when loans are consolidated. This lends support to using the current proportion of debt and equity at expected costs of debt and equity.
- When valuing another organisation for acquisition, use your organisation's WACC as that is what the acquired organisation's cash flows will be valued at when consolidated.
- When valuing another organisation for acquisition, use that organisation's WACC.
- Do both of the above to identify whether you and the other organisation value it differently, with potential impacts on acquisition costs.
- When valuing an organisation in the same industry, use the industry WACC – this may be based on the view that an optimal capital structure is obtainable and, given the optimal mix is difficult to observe, one uses the industry average cost of capital instead.
- When valuing an organisation in a different industry, use the industry WACC with an adjustment for your debt position.
- Business units within an organisation each have their own set of risks, hence it is appropriate to use a different cost of capital when ranking opportunities.

APPENDIX C – RECOMMENDED READING LIST

Discount rates

Smith, L, 1990. Inflation in project evaluation, *CIM Bulletin*, 83(935):129-133.

Smith, L, 1995. Discount rates and risk assessment in mineral project evaluations, *CIM Bulletin*, 88(989):34-43.

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Real options

Clemen, R T, c1996. *Making Hard Decisions: An Introduction to Decision Analysis* (Duxbury Press: Belmont).

Copeland, T E and Antikarov, V, c2001. *Real Options: A Practitioner's Guide* (Texere: New York).

Howell, S, Stark, A, Newton, D P, Paxson, D, Cavus, M, Azevedo-Pereira, J and Patel, K, 2001. *Real Options: Evaluating Corporate Investment Opportunities in a Dynamic World* (Financial Times Prentice Hall).

Schwartz, E S and Trigeorgis, L, c2001. *Real Options and Investment Under Uncertainty: Classical Readings and Recent Contributions* (MIT Press: Cambridge).

Value at risk

Lai, F J and Stange, W, 2009. Using value at risk for integrated project risk evaluation, in *Proceedings Project Evaluation 2009*, pp 223-232 (The Australasian Institute of Mining and Metallurgy: Melbourne).

Stange, W and **Cooper, B**, 2008. Value options, risk and flexibility in plant design and operations, in *Proceedings Metallurgical Plant Design and Operating Strategies (MetPlant 2008)*, pp 207-222 (The Australasian Institute of Mining and Metallurgy: Melbourne).

Whittle, G, **Stange, W** and **Hanson, N**, 2007. Optimising project value and robustness, in *Proceedings Project Evaluation Conference 2007*, pp 147-156 (The Australasian Institute of Mining and Metallurgy: Melbourne).

APPENDIX D – TECHNICAL ECONOMIC EVALUATION GUIDELINES COMMITTEE MEMBERS

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APPENDIX 2

GLOSSARY OF USEFUL VALUATION TERMS

APPENDIX CONTENTS

Glossary of useful valuation terms

M J Lawrence

GLOSSARY OF USEFUL VALUATION TERMS

Advanced exploration areas – mineral properties where considerable exploration has been undertaken and specific targets have been identified that warrant further detailed evaluation, usually by drill testing, trenching or some other form of detailed geological sampling. A Mineral Resource estimate may or may not have been made but sufficient work will have been undertaken on at least one prospect to provide both a good understanding of the type of mineralisation present and encouragement that further work will elevate one or more of the prospects to the Mineral Resource category (VALMIN Code, Definition D20).

Competence – means having relevant education, qualifications and experience, professional expertise and holding appropriate licences (where required) so as to have a reputation that gives authority to statements made in relation to a particular matter (VALMIN Code, Definition D7 and see Clauses 18 - 23).

Development projects – mineral properties for which a decision has been made to proceed with construction and/or production, but which are not yet commissioned or are not yet operating at design levels (VALMIN Code, Definition D20).

Expert – it means a **Competent** (and **Independent**, where relevant) natural person who prepares and has overall responsibility for the Valuation Report. He/she must have at least ten years of relevant **minerals industry** experience, using a relevant **specialist** for specific tasks in which he/she is not **Competent**. An **expert** must be a corporate member of an appropriate, recognised professional association having an enforceable Code of Ethics, or explain why not (for the full definition see VALMIN Code, Definition D10 and its Clause 17).

Exploration areas – mineral properties where mineralisation may or may not have been identified, but where a Mineral Resource has not been identified (VALMIN Code, Definition D20).

Fair value – it is an accountancy term used for values envisaged to be derived under *any and all conditions*, not just those prevailing in an open market for the normal orderly disposal of assets. Being a transaction price it reflects both existing and alternative uses, too. It is also a legal term for values involved in dispute settlements which may not also meet the strict **market value** definition. Commonly, it reflects the service potential of an asset, ie value derived by DCF/NPV analysis, not merely the result of comparable sales analysis. It is still the ‘amount for which an asset could be exchanged, or a liability settled, between knowledgeable willing parties in an arm’s length transaction’ (IVSC definition).

Forced sale value (liquidated value) – it is the amount reasonably expected to be received from the sale of an asset *within a short time frame for completion* that is too short to meet the **market value** definition. This definition requires a reasonable marketing time, having taken into account the asset’s nature, location and the state of the market). Usually it also involves an *unwilling* seller and buyers who have knowledge to the disadvantage of the seller.

Going concern value – it is a business valuation concept rather than one relating to individual property valuation. It is the value of an operating business/enterprise (ie one

that is expected to continue operating) *as a whole* and it includes goodwill, special rights, unique patents or licences, special reserves, etc. Apportionment of this total value may be made to constituent parts, but none of these components constitute a basis for **market value**.

Highest-and-best-use – for physical property, it is the reasonably probable and legal use of property, which is physically possible, appropriately supported and financially feasible, that results in the *highest value*. In the case of personal property, it is the same with the additional qualification that the highest value must be in the appropriate market place, consistent with the purpose of the appraisal. It may be, in volatile markets, the holding for a future use.

Independent/independence – means that the **expert** and/or **specialists** must be able to satisfy any relevant legal tests of **independence** and must be, and be perceived to be, willing and able to undertake an impartial assessment or valuation and to prepare an independent expert report that is free of bias. To this end, the **expert and/or specialists** and their immediate families may not have a significant pecuniary or beneficial interest in the commissioning entity; or the owners or promoters (or parties associated with them) of any of the **mineral assets** or securities that are the subjects of the **technical assessment/valuation** to be prepared; or the offerer and target companies in the case of takeover situations; or in any of the **mineral assets** or securities that are the subjects of the **technical assessment/valuation**; or the outcome of the **technical assessment valuation**. As at April 2005, ASIC Policy Statement 75, 'Independent Expert Reports to Shareholders', ASIC Practice Note 42 'Independence of Experts' Reports' and ASIC Practice Note 43 'valuation reports and profit forecasts' were current and provided instructions and guidance concerning the Independence of Experts and the preparation of Reports and valuation statements required for purposes regulated by the Australian Corporations Act (*VALMIN Code*, Definition D13 and see Clauses 24-27). From 5 July 2007 Policy Statements and Practice Notes were withdrawn and superseded by Regulatory Guides (RG). Their replacements were RG111 (content of expert reports) and RG112 (Independence of experts), but currently dated October 2007. The VALMIN Code (2005) Clause 50 further outlines the recommended 'content of a relevant report'. Hence, the person making the **valuation** must have no **material** pecuniary or beneficial (present or contingent) interest in any of the **mineral assets** being assessed or valued, other than professional fees and reimbursement of disbursements paid in connection with the assessment or Valuation concerned; or any association with the commissioning entity, or with the owners or promoters (or parties associated with them) likely to create any apprehension of bias.

Independent Expert Reports – are **public reports** that may be required by the *Australian Corporations Act*, the Listing Rules of ASX or of other recognised stock exchanges or for any other purpose that may involve the **technical assessment and/or valuation of mineral or assets** and/or securities. It must be prepared by an **expert** who is **independent**. The assistance of **specialists** who are also **independent** may be necessary, depending on whether or not the **expert** has expertise in all aspects of the **technical assessment and/or valuation**, and on the magnitude of the task (*VALMIN Code*, Definitions D14 and see Clause 12).

Investment value (worth) – this is the value of a specific asset to a specific investor(s) for identified investment objectives or criteria. It may be higher or lower than **market value** and is associated with **special value**.

Market value (IVSC definition) – it is the result of an objective Valuation of specific identified ownership rights to a specific asset as at a given date. It is the value in exchange not **value-in-use** set by the market place. It is the ‘estimated amount for which a property should be exchanged on the date of valuation between a willing buyer and a willing seller in an arm’s length transaction *after proper marketing* wherein the parties had acted knowledgeably, prudently, and without compulsion’.

Material/materiality – means that the contents and conclusions of a report, any contributing assessment, calculation or the like and data and information are of such importance that their inclusion or omission from a **technical assessment** or **valuation** may result in a reader of the report reaching a different conclusion than would otherwise be the case. The determination of what is material depends on both qualitative and quantitative factors. Something may be material in the qualitative sense because of its very nature, such as, for example, country risk. In the case of quantitative issues, the materiality of data can be assessed in terms of the extent to which the omission or inclusion of an item could lead to changes in total value according to the guidelines of the Australian Society of Accountants’ Standard AAS5, ie **material** data (or information) is such that the omission or inclusion of it could lead to changes in total value of greater than ten per cent – between five and ten per cent it is discretionary (VALMIN Code, Definition D16). **Material** data (or information) is also that which would be reasonably required in order to make an informed assessment of the subject of the report. Also the Supreme Court of New South Wales has stated that something is **material** if it is significant in formulating a decision about whether or not to make an investment or accept an offer.

Mineral(s) – any naturally occurring material found in or on the Earth’s crust, that is useful to and/or has a value placed on it by humankind, excluding crude oil, natural gas coal-based methane, tar sands and oil shale which are classified as Petroleum as defined in D25 (VALMIN Code, Definition D19). The term specifically includes coal; shale and materials used in building and construction; uranium and gemstones (eg diamonds).

Mineral asset(s) (Resource Assets or Mineral Properties) – means all property including, but not limited to **real property**, intellectual property, mining and exploration tenements held or acquired in connection with the exploration of, the development of and the production from those tenements; together with all plant, equipment and infrastructure owned or acquired for the development, extraction and processing of Minerals in connection with those tenements. Most can be classified as **exploration areas, advanced exploration areas, predevelopment projects, development projects** or **operating mines** (VALMIN Code, Definition D20).

Mining industry (also minerals industry and extractive industry) – the business of exploring for, extracting, processing and marketing minerals (VALMIN Code, Definition D23).

Operating mines – mineral properties, particularly mines and processing plants that have been commissioned and are in production (VALMIN Code, Definition D20).

Personal property – it covers all items other than real estate and may be tangible (like a chattel or goods) or intangible (like a patent or debt). It has a moveable character.

Predevelopment projects – mineral properties where Mineral Resources have been identified and their extent estimated (possibly incompletely) but where a decision to proceed with the development has not been made. Mineral properties at the early assessment stage, properties for which a decision has been made not to proceed with

development, properties on care and maintenance and properties held on retention titles are included in this category if mineral or petroleum resources have been identified, even if no further valuation, technical assessment, delineation or advanced exploration is being undertaken (VALMIN Code, Definition D20).

Price – it is the amount paid for a good or service and it is a historical fact. It has no real relationship with **value**, because of the financial motives, capabilities or special interests of the purchaser; and the state of the market at the time.

Property-with-trading-potential – refers to the valuation of specialised property (eg hotel, petrol station, restaurant, etc) that is sold on an operating or going concern basis. It recognises that assets other than land and buildings are to be included in the **market value** and it is often difficult to separate the component values for land and property.

Public reports – include, but are not limited to company annual and quarterly and other reports to ASX or other recognised stock exchanges or as may be required by law. By way of guidance if the report is likely to be sent to all, or substantially all the shareholders of a company, it will be a **public report**; or if the report is likely to be released to ASX or another recognised stock exchange, it will be a **public report**. If the commissioning entity is not a listed company and the report is likely to be read by entities from which funds may be raised under the Corporations Act without the use of a disclosure document, it is unlikely to be a **public report** (VALMIN Code, Definition D28).

Real estate – it is a physical concept, including land and all things that are a natural part of the land (eg trees and minerals). In addition it includes all things effectively permanently attached by people (eg buildings, site improvements, and permanent physical attachments, like cooling systems and lifts) on, above or below the ground.

Real property – it is a non-physical, legal concept and it includes all the rights, interests and benefits related to the ownership of real estate and normally recorded in a formal document (eg deed or lease). The rights are to sell, lease, enter, bequeath, gift, etc. There may be absolute single or partial ownership (subject to limitations imposed by government, like taxation, planning powers, appropriation, etc). These rights may be affected by restrictive covenants or easements affecting title; or by security or financial interests, say conveyed by mortgages.

Salvage value – it is the expected value of an asset at the end of its economic life (ie being valued for salvage disposal purposes rather than for its originally intended purpose). Hence, it is the value of property, excluding land, as if disposed of for the materials it contains, rather than for its continued use, without special repairs or adaptation.

Scrap value (residual value) – it is the remaining value (usually a net value after disposal costs) of a wasting asset at the end of a prescribed or predictable period of time (usually the end of its effective life) that was ascertained upon acquisition.

Specialist – it means a **Competent** (and **Independent**, where relevant) natural person who is retained by the expert to provide subsidiary reports (or sections of the valuation report) on matters on which the expert is not personally expert. He/she must have at least five years of suitable and preferably recent **minerals industry** experience relevant to the subject matter on which he/she contributes. A **specialist** must be corporate member of appropriate, recognised professional association having an enforceable Code of Ethics, or explain why not (for the full definition see VALMIN Code, Definition D10 and its Clause 17).

Special value – an extraordinary premium over and above the **market value**, related to the specific circumstances that a particular prospective owner or user of the property attributes to the asset. It may be a physical, functional or economic aspect or interest that attracts this premium. It is associated with elements of **going concern value** or **investment value** since it also represents synergistic benefits. In a strict sense it could apply to very specialised or special purpose assets which are rarely sold on the open market, except as part of a business, because their utility is restricted to particular users. In some circumstances, it may be the lower value given by **value-in-use**.

Technical assessment reports – involves a review of those project elements such as mining engineering, metallurgy, environmental impacts, capital and operating costs and actual and/or projected production that may contribute to the actual and/or potential economic output from **mineral assets** as may be required to assess the economic benefit of those assets and then to determine their **technical value** (VALMIN Code, Definition D35).

Technical value – it is an assessment of a **mineral asset's** future net economic benefit at the **valuation date** under a set of assumptions deemed most appropriate by an **expert** or **specialist** (the **valuer**) excluding any premium or discount to account for such factors as market or strategic considerations (VALMIN Code, Definition D36).

Transparent/transparency – literally means 'easily seen through, clear and unmistakable, free from affectation and disguise.' For the purposes of the VALMIN Code, these qualities *must* apply to the data and information used as the basis of a valuation or a technical assessment, including the assessment of resources/reserves, mining, processing and marketing issues, the valuation approach adopted and the methodology or methodologies used, all of which must be clearly set out in the Report (VALMIN Code, Definition D31 and see Clauses 28 - 31).

Valuation – it is the **value** of a **mineral asset**, mineral property or security (VALMIN Code, Definition D40).

Valuation date – the reference date to which a **valuation** applies. Depending on the circumstances, it could be different to the date of completion or signing of the valuation report or the cut-off date of the available data (VALMIN Code, Definition D41).

Value (also **valuation**, which is the result of determining **value**) – in simple terms it is the estimated likely future **price** of a good or service at a specific time, but it depends upon the particular qualified type of value (eg **market value**, **salvage value**, **scrap value**, **special value**, etc). There is also a particular value for tax and rating, or insurance purposes. **Fair market value** (market value or **value**) – it is the object and result of the **valuation**. It is the estimated amount of money (or the cash equivalent of some other consideration) for which the **mineral asset** should change hands on the **valuation date**. It must be between a willing buyer and a willing seller in an arm's length transaction in which each party has acted knowledgeably, prudently and without compulsion. It is usually comprised of two components, the underlying or **technical value** and a premium or discount, relating to market, strategic or other considerations (VALMIN Code, Definition D43).

Value-in-use – in contrast to **highest-and-best-use**, it is the specific value of a specific tangible asset that has a specific use to a specific user. It is not market-related. The focus is on the value that a specific property contributes to the enterprise of which it is a part (being part of a **going concern valuation**). It measures the contributory value of a specified asset(s) used within that specific enterprise, although it is not the **market value** for that

individual asset. It is the value-to-the-owner/entity/business in accountancy terms and may be the lower of net current replacement cost and its recoverable amount. It is also the net present value of the expected future net cash flows from the continued use of that asset, plus its disposal value at the end of its useful life (**scrap value**). At the **valuation date**, there must be recognition of its existing use by a particular user. This is in contrast to the alternative reasonable use to which an asset might be put by unspecified owner(s).

Valuer (also valuator [Canada] or appraiser [USA]) – it is either the **expert** or **specialist** (Qualified Person in Canada) who is the natural person responsible for the Valuation to determine the **fair market value** after consideration of the technical assessment of the **mineral asset** and other relevant issues. They must have demonstrable **competence** (and **independence**, when required).

APPENDIX 3

PRO FORMA OPERATIONS REPORT

APPENDIX CONTENTS

Pro forma operations report

J Dunlop

COMPANY OR JOINT VENTURE LOGO

NAME OF MINE OR PROJECT

MONTHLY ACTIVITY REPORT

Month and Year

Prepared by:

Name of mine or project operator

Ops Report No: ABC001

NAME OF MINE OR PROJECT

MONTHLY ACTIVITY REPORT

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Note – the monthly report contents could also include:

- *management summary*
- *key milestones*
- *progress and explanations of deviations from budget and/or forecast targets*
- *risk register*
- *key performance indicators (KPIs)*
- *other.*

References could also be made to the so-called ‘monthly project status report’, ie a short concise document focusing on whether or not the project is on track compared to budget and/or forecast targets, etc.

1.0 EXECUTIVE SUMMARY

Set out a summary of all the sections which follow. It should be possible for readers to glean the main operational points by reference to this section only.

2.0 CORPORATE DEVELOPMENT

Discuss the major activities for the month.

2.1 Corporate matters

Status

2.2 Project development

2.2.1 Project 1

Status

2.2.2 Project 2

Status

2.2.3 Project 3

Status

2.2.4 Project 4

Status

2.3 Public relations

Status

2.4 Regulatory issues

Status

3.0 MINERAL EXPLORATION

General overview

3.1 Resource extension projects

3.1.1 Prospect 1

Status

3.1.2 Prospect 2

Status

3.2 Resource definition projects

3.2.1 Prospect 1

Status

3.3 Advanced exploration projects

3.3.1 Prospect 1

Status

3.3.2 Other prospects

Status

3.4 Exploration projects

3.4.1 Project 1

Status

3.4.2 Other projects

Status

4.0 MINING PROJECT NAME

4.1 General overview

Status

4.2 Mine operations

4.2.1 Mine development

Status

4.2.2 Open pit operations

Status

4.2.3 Underground operations

Status

4.3 Milling operations

4.3.1 Plant section 1

Status

4.3.2 Plant section 2

Status

4.3.3 Plant section 3

Status

4.3.4 Plant section 4

Status

4.4 Maintenance and engineering

4.4.1 Fixed plant

Status

4.4.2 Mobile plant*Status***4.4.3 Capital works***Status***4.5 Product handling***Status***4.6 Shipping***Status***5.0 OCCUPATIONAL HEALTH SAFETY AND TRAINING***General overview***5.1 Health and safety***Accident and injury statistics***5.2 Training***Occupational health, safety and training activities***5.3 Hazard analyses and risk management***Status***6.0 PERSONNEL AND MANNING***Text***6.1 Corporate***Status, with organisation chart. Record of arrivals and departures.***6.2 Operations***Status, with organisation chart. Record of arrivals and departures.***7.0 ENVIRONMENTAL MANAGEMENT***Overview***7.1 Environmental management***Status, with reference to regulatory obligations.***7.2 Environmental monitoring***Status***7.3 Occupational health issues***Status*

8.0 ADMINISTRATION*Text***8.1 Head office***Status***8.2 Site office***Status***8.2.1 Administration***Status***8.2.2 Warehouse and stores***Status***8.3 Camp/village administration***Status***9.0 MANAGEMENT COST REPORT***Cost summary, referring to cost report in the appendix.**Cost variance report including reference to unit costs and key performance measures, against the annual budget or adjusted forecast.***APPENDIX I***Management cost report.**Appendices could also include graphs and other information or data necessary to elucidate statements, etc presented in the report.*

APPENDIX 4

PRO FORMA RISK MANAGEMENT REPORT

APPENDIX CONTENTS

Pro forma risk management report

J Dunlop

ABC RESOURCES LIMITED ('COMPANY')

OVERVIEW

In managing risk, it is the company's practice to take advantage of potential opportunities while managing potential adverse effects. This policy sets out a summary of the company's risk management system and processes, and the company's risk profile.

1. ROLE OF THE BOARD AND DELEGATED RESPONSIBILITY

The board is responsible for reviewing the company's policies on risk oversight and management and satisfying itself that management has developed and implemented a sound system of risk management and internal control.

Implementation of the risk management system and day-to-day management of risk is the responsibility of the managing director, with the assistance of the operational risk sponsor and other senior management as required.

2. ROLE OF THE MANAGING DIRECTOR AND ACCOUNTABILITIES

The managing director has responsibility for identifying, assessing, monitoring and managing risks. The managing director is also responsible for identifying any material changes to the company's risk profile and ensuring, with approval of the board, the risk profile of the company listed in this policy are updated to reflect any material change. The managing director may delegate some of his responsibilities to the board appointed operational risk sponsor who is to report to the managing director on an ongoing basis, but at least monthly.

The managing director is required to report on the progress of, and on all matters associated with, risk management as a standing item at each board meeting. The managing director is to report to the board as to the effectiveness of the company's management of its material business risks, at least annually.

3. AUTHORITY OF THE MANAGING DIRECTOR

In fulfilling the duties of risk management, the managing director may have unrestricted access to company employees, contractors and records and may obtain independent expert advice on any matter they believe appropriate, with the approval of the board.

4. RISK PROFILE

The company considers that any risk that could have a material impact on its business should be included in its risk profile. The risk profile of the company as at the date this policy was adopted by the board can be categorised as follows:

- market-related
- financial reporting
- operational
- environmental

- human capital
- sustainability
- occupational health and safety
- political
- strategic
- technological
- ethical conduct
- economic cycle/marketing
- reputation
- legal and compliance.

5. ADDITIONAL POLICIES AND PRACTICES

The company maintains a number of policies and practices designed to manage specific business risks. These include the following:

- *Risk management policy.*
The company has a risk management policy designed to manage risk effectively at management and staff level. It encourages a risk management culture based on a shared vision, purpose, goals and critical success factors. The risk management policy sets out the role of the management team and individual staff.
- *Operational risk management framework.*
The company has an operational risk management framework to assist it to implement its board risk management policies.
- *Audit committee and audit committee charter.*
The company has formed a separate audit committee, which has the role of, among other things, monitoring and reviewing the integrity of the financial reporting of the company and any significant financial reporting judgements. It also reviews the company's internal financial control system and, unless expressly addressed by a separate risk committee or by the board itself, risk management systems. The role of the audit committee is set out in the company's audit committee charter.
- *Insurance program.*
The company maintains comprehensive business insurances, which are reviewed annually.
- *Regular budgeting and financial reporting.*
The company has regular budgeting in place. It is the role of the audit committee (or its equivalent) to review the integrity of the financial reporting of the company. The audit committee is to ensure the board is fully aware of matters which may significantly impact the financial conditions or affairs of the business.
- *Clear limits and authorities for expenditure levels.*
The company's board charter sets out materiality thresholds. These include quantitative and qualitative thresholds as well as triggers for the materiality of contracts.
- *Procedures/controls to manage environmental and occupational health and safety matters.*

- *Procedures for compliance continuous disclosure obligations under the Australian Stock Exchange listing rules.*

The company's compliance procedures have been designed for the purpose of ensuring the company complies with its continuous disclosure obligations.

- *Procedures to assist with establishing and administering corporate governance systems and disclosure requirements.*

The company has adopted a corporate governance manual, which contains policies and procedures to assist the company establish and maintain its governance practices.

6. RESPONSIBILITY TO STAKEHOLDERS

The company considers the reasonable expectations of stakeholders particularly with a view to preserving the company's reputation and success of its business. Factors that affect the company's continued good standing are included in the company's risk profile.

7. CONTINUOUS IMPROVEMENT

The company's risk management system is evolving. It is an ongoing process and it is recognised that the level and extent of the risk management system will evolve commensurate with the development and growth of the company's activities.

RISK MANAGEMENT POLICY SUMMARY

The board has adopted risk management policies. Under the policies, the board delegates day-to-day management of risk to the managing director. The policy sets out the role of the managing director and the board appointed operational risk sponsor and their accountabilities. It also contains the company's risk profile and describes some of the policies and practices the company has in place to manage specific business risks.

The managing director is required to report on the progress of, and on all matters associated with, risk management as a standing item at each board meeting. The managing director is to report to the board as to the effectiveness of the company's management of its material business risks at least annually.

The board is responsible for approving the company's policies on risk oversight and management and satisfying itself at least annually that management has developed and implemented a sound system of risk management and internal control.

The board has formalised and documented the management of its material business risks. This system includes the preparation of a risk matrix by third party consultants in consultation with the board and management to identify the company's material business risks and risk management strategies for these risks. In addition, the process of management of material business risks is allocated to members of senior management. Risk is a standing item at each scheduled board meeting and the risk matrix is reviewed and updated as required.

The board also receives a written assurance from the chief executive officer and the chief financial officer that to the best of their knowledge and belief, the declaration provided by them in accordance with section 295A of the *Corporations Act* is founded on a sound system of risk management and internal control and that the system is operating effectively in relation to financial reporting risks.

This Policy incorporates some material from 'Principle 7: Recognise and Manage Risk – Guide for Small-Mid Market Capitalised Companies' produced by ASX Markets Supervision Pty Ltd, Deloitte Touche Tohmatsu and a general guideline prepared by lawyers Blakiston & Crabb (now Gilbert and Tobin).

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FOREWORD

There are many excellent writings and even handbooks on various aspects of mining and management. This Handbook is the first comprehensive treatise I have seen describing all the important aspects of managing a mining company in one volume.

Modestly named Mine Managers' Handbook, it includes topics such as corporate strategy, leadership and world markets for minerals. Written by experts from industry, consulting firms and academia, it will be of great value also to corporate executives, directors of mining companies, students and, indeed, to all those wishing to understand the industry. Several of the chapters and sections are relevant to industrial activity generally. While written primarily for Australian conditions, much of the content will be valuable to readers in other countries.

Had it been written 50 years ago, the list of contents would have been shorter. Not only was business environment then much simpler but economic development in Australia, and particularly mineral projects that opened up inland areas, had the unqualified support of governments and the community. Many of the present regulatory requirements and approval processes did not exist. Today the minerals industry is subject to close scrutiny. Meeting the community's requirements and informing the public about the industry is now equally important to applying best practice to the operational and economic aspects.

The minerals industry is vital to Australia; we are all stakeholders. Gold discoveries in the second half of the 19th century were instrumental in Australia becoming a nation. The great mineral discoveries and developments in the 1960s and 1970s established Australia as a major supplier of minerals to the world and created a new level of prosperity. In the last ten years or so the demand for minerals by China has underwritten the Australian economy and continues to do so.

Australia is fortunate to have abundant mineral resources but there are other countries similarly endowed and, in the past, strong demand and high prices for minerals have alternated with periods of surplus supply. During the dot.com boom in the second half of the 1990s prices fell to historically low levels and the minerals industry was spoken of as out of date; the 'old economy'. To survive the downturns and be able to benefit in good times it is essential to be highly efficient and globally competitive.

Another characteristic of the minerals industry is that even the largest orebodies will be eventually mined out. New deposits must continue to be discovered to be able to maintain, let alone expand, the industry. In poorly explored parts of the world such finds may still be made on or near the surface, but this is increasingly unlikely in Australia. Successes in minerals exploration are rare, very few prospects become orebodies. Deeper discoveries will be even more difficult to make than the shallower finds in the past. To succeed, we need to be persistent and apply the best available exploration know-how and technology.

Applying world's best practice in all aspects of the industry is absolutely vital to its future. The Organising Committee, the Editor and the authors of the AusIMM Mine Managers' Handbook have made a unique contribution towards this. We are all indebted to them.

Sir Arvi Parbo AC, HonFAusIMM

INTRODUCTION

Thank you for being committed enough to your career and the industry to pick up this handbook. Whether you're a mine manager, or soon to be one, or are just interested in the methods and motivations of mine managers, this is a reference – a ready resource – written by mine managers for mine managers.

It is intended to guide mine managers – to point the way – as the myriad of management problems confront the practising manager every day. It is not intended to be prescriptive, but rather to set out what is currently considered to be best practice, and by so doing, point to the way most problems can be dealt with, at least by reference to accepted sound mine management practice.

It is not a handbook intended to be read from front to back. Like all good references, it is designed to be accessed, issue by issue, as the need arises.

In recent years, the breadth of the management dimension confronting mine managers has grown exponentially, to the point where, depending on the location, the skill set may call for not just a manager, but also the skill sets of a father confessor, a magistrate, a public relations expert, an expert witness, a shire councilor or diplomat. It is with this in mind that the chapters of this handbook have been assembled.

Origins of the Mine Managers' Handbook

The idea of the Mine Managers' Handbook came about during planning of The AusIMM's inaugural Mine Management Conference in 2006 with some preliminary work undertaken by the Chair of that event, Richard Knight. It was not until 2010, however, that a formal proposal was put before the AusIMM Publications Committee and approved by The AusIMM Board, later that same year.

The project was taken up by the AusIMM Mining Society from which a steering committee was formed, comprising a group of distinguished mining engineers and mine managers including Chris Carr, Paul Harper, Emeritus Professor Odwyn Jones, Professor Brian White, and chaired by John Dunlop. By the end of 2010, a plan and budget had been prepared and a table of contents notionally agreed to.

How the Mine Managers' Handbook was written

The steering committee decided that the most appropriate way to assemble each chapter of the handbook would be to source mine managers with specific expertise in the subject matter and ask them to become an author for that section. Gradually, each chapter took shape with an author team, headed by a 'chapter editor'. The chapter editors, in turn, reported in to the editor 'in chief', John Dunlop, who coordinated each chapter, guided the process and reported back to the steering committee. The main body of the text was assembled during calendar 2011.

About the editors and authors

The editors and authors of each chapter will be seen as you browse through the handbook. They all have extensive experience in their respective topics and may be considered both authoritative and in a position to present 'industry best practice'. Occasionally, views will be expressed that may not necessarily be endorsed by all; but they have been presented none the less. In all cases, the views are those of the authors and are not to be taken as the official views or policy of The AusIMM.

Objectives of the Mine Managers' Handbook

Sometimes it is easier to describe things by reference to what they are not. This could well be such a case here, in the sense that this handbook is not a textbook. It is not prescriptive. It does not pretend to

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present how things should be done – rather, it sets out how managers have dealt with particular issues in the past, or how current day managers approach the issues in question that confront them every day.

Textbooks are perhaps best viewed as repositories of knowledge; assemblages of theory, rules and practice, backed up by a combination of academic rigor and proven practice. This handbook differs from a textbook in that sense by providing an insight into the breadth of modern day mine management, thus alerting practitioners to the many management issues that may need to be addressed before they become an unexpected and unwelcome crisis.

The handbook may therefore alert the reader to where the potential issues may lie concealed – the textbook, on the other hand, may well be the place to go in order to find an appropriate solution. In a nutshell, that is why this monograph was, from the outset, envisaged to be a handbook.

Keeping the Mine Managers' Handbook up to date

The steering committee wishes to see this monograph grow in use with time and become a flagship AusIMM publication for all mining managers, be they aspiring, new, or established.

The hard work of getting the first edition out is now behind us. The challenge is now thrown down to those who come after us to keep the handbook current, and therefore relevant, even as the industry changes with each passing decade.

We'd expect to see new sections appearing with each reprinting and encourage the establishment of a new steering committee as circumstances dictate, to ensure that this happens.

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Xstrata's suite of Australian operations employs around 17 500 Australians, including contractors. Xstrata is a major contributor to the Australian economy, having generated \$60 billion of revenue since 2002.

At least one per cent of Xstrata Group's profits before tax are set aside every year to fund initiatives that benefit the communities in which it operates. In Australia, Xstrata contributed \$25 million to the communities in which it operated through extensive corporate social involvement programs in 2011.

Xstrata in the Northern Territory

Xstrata Zinc operates the McArthur River Mine (MRM) in a remote corner of the Northern Territory. MRM is a zinc-lead-silver open cut mining operation that has become one of the world's largest providers of zinc in bulk concentrate form, and employs around 560 people including contractors.

Xstrata in Western Australia

Xstrata Nickel Australasia (XNA) is based in Perth, Western Australia. It is composed of the Cosmos and Sinclair Nickel operations, which are located at the heart of Australia's productive Leinster-Mt Keith nickel sulfide district. XNA's operations include the Cosmos underground mine and concentrator,

which has the capacity to treat 460 000 tonnes of ore per year (2011), and an underground mine and concentrator at Sinclair, which has the capacity to treat 350 000 tonnes of ore per year (2011). The concentrate produced is then trucked to the Esperance Port and shipped to the Xstrata Nickel Smelter in Sudbury, Ontario. XNA's workforce across the sites consists of approximately 200 employees and 400 contractors.

Xstrata in Queensland

Xstrata's Coal, Copper, Zinc and Technology commodity businesses manage 17 operations and a number of growth projects employing more than 10 500 people throughout the State.

The operations in Queensland span from copper and zinc mining and processing facilities in the north-west minerals province and across North Queensland, to Xstrata Coal's mining operations in the resource-rich Bowen Basin across to the Abbot Point Coal Terminal. They also include the Xstrata Technology business, which operates out of Brisbane and Townsville, working with clients throughout the world to improve the efficiency of the global minerals processing and metals smelting the refining industries.

As an employer and local business partner, Xstrata contributes to the sustainable growth of regional communities in Queensland, making significant contributions to export revenues, royalties and direct and indirect employment. In 2011, Xstrata contributed more than \$4.2 billion to the Queensland economy.

Xstrata in New South Wales

Headquartered in Singleton in the Hunter Valley, Xstrata Coal New South Wales (NSW) operates eight mining complexes across the State, incorporating 14 open cut and underground mining areas and eight coal handling processing plants.

As an employer and local business partner, Xstrata contributes to the sustainable growth of regional communities and makes significant contributions to NSW export revenues, royalties and direct and indirect employment. In 2011, Xstrata contributed more than \$2.6 billion to the NSW economy.

Xstrata Coal NSW's operations are located across four districts: Hunter Valley, Newcastle, Western Districts and Southern Districts.

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