GERMAN - MONGOLIAN INSTITUTE
FOR RESOURCES AND TECHNOLOGY

GERMAN - MONGOLIAN INSTITUTE
FOR RESOURCES AND TECHNOLOGY

The present work was submitted to the Faculty of Engineering

Optimization of Project Cost Estimation to Minimize Risk: A Case Study

Bachelor Thesis

by

Tseveendorj Gan-Erdene

Supervisor 1 / Examiner 1	**Dr. Enkhzaya Chuluunbaatar**
Supervisor 2 / Examiner 2	**David Knapp**
Advisor	**Kevin Fleming**

Ulaanbatar/Nalaikh, 2020.06.08

Statutory Declaration

Tseveendorj Gan-Erdene	14405649789986
Last Name, First Name	Student ID Number

I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis

xxx

I did not use any sources other than those stated. In case that the work is additionally submitted on a data medium, I declare that the written and the electronic form are completely identical. The work was not submitted in the same or similar form to any examination authority.

Ulaanbaatar 2020.06.08	Tseveendorj
Place, Date	Signature

Contents

Table of Figures

Acknowledgement

The process of writing this thesis has been truly a unique experience. The current state of the world has to do with this in one part for sure. Though, an even greater impact was felt from using the knowledge amassed from the last 5 years of my studies to complete this task and realizing that I've learned so much during this time and yet there is much more to learn.

I've been lucky to have assigned myself supportive and helpful supervisors for this thesis. Also, the tremendous amount of support from GMIT and the people who make it, as well as the kind-hearted people at Square One can't be stressed enough. Without the help and support of these people, I probably wouldn't be writing this. Thus, I would like to offer my sincere gratitude to those I've mentioned.

Lastly, I would like to thank my mother. Without her support and warm meals, I don't know where I would be.

Abstract

With the rapid development of technology in the 20th and 21st century, the breadth and depth of development in most sectors have increased exponentially. As a result, organizations have shifted towards a project-oriented structure for their operations. Today projects are implemented in specific steps which govern the outcome. In the initiation and planning phase, complete characterization of the project is written and possible risks that are associated with the project are analyzed. Effective projects have proper assessment of their capabilities and plan their resources accordingly. While the amount of research done is most often correlated with the success of the project, there are still many unknown factors and changes to be made later in the life cycle of a project. Thus, it is beneficial to investigate the initial design stage of a project and research methods to improve the quality of assessment made during this time so that it has the least amount of effect on the planned process during implementation. During the planning phase of projects, one key area of research is that of cost estimation. Cost estimation is a process that strongly influences the later phases of a project. A properly done cost estimation is a concrete way of avoiding pitfalls and minimizing risk in the future. Thus, the goal of this thesis is to investigate the optimization of project cost estimation in the initial stages to minimize risk later in the lifecycle of the project, utilizing the Square One case study.

Introduction

Overview

Construction projects, regardless of size, must deal with risks and uncertainties (1) which then must be effectively managed in order to ensure fulfillment of its objectives and success of the project (2). Due to this, all initiatives and projects must be prepared to take on these risks and proactively handle them while setting in effect proper measures for any uncertainty to maximize their opportunities and mitigate the threats they can present in the event of their occurrence. Risk, in terms of a project, is an unknown event or circumstance that would lead to a positive or negative effect if it happens. On the other hand, uncertainty is defined as the lack of knowledge of such future events. Furthermore, the term Project is described as “a complex, non-routine, one-time effort limited by time, budget, resources, and performance specifications designed to meet customer needs” (3). Due to the inherent fact that the complex nature of the world prohibits exact prediction of the future and a project is affected by many factors such as economics, politics, climate, and culture, the concept of risk is an important one (4). Risk management is an iterative process that must be applied through the whole extent of a project life cycle and should serve as a guiding system. Subsequently, it is the job of the project managers to control risk to the extent of their abilities to generate realistic cost estimates. During the planning phase the general frame of the project is fabricated. These include several activities, one of which is the procedure of project cost estimation. Cost estimation is the process undertaken to calculate expected costs of the project through analysis of the project and the environment it is executed in. This can be a challenging process due to the lack of information and a variety of unknown factors exist(3).

Construction projects, like any other project, require complex undertakings that are generally made up of tens to hundreds of activities called work packages. The execution of the work packages can be composed of individuals from a variety of fields using different methods and tools. This level of complexity has a direct effect on the uncertainty of project cost estimations. Thus, by improving the process of project cost estimation we can minimize the risk associated with the project and lead to a better outcome.

Budgeting, planning, evaluation of resources, risk analysis, project improvement investment analysis, calculation of performance is just a few of the reasons for implementing project cost

estimation (5). Currently, methods for estimating a construction project's cost ranges from an educated guess by experienced personnel to a modern systematic complex cost estimation model (6). The extent to which a cost estimation study can be carried out purely depends on the circumstance. Major factors which influence the circumstance are the availability of human resource, financial resource, technological resource, and time. Typically, quicker methods require less input but tend to be inaccurate. Likewise, a more in-depth method will require time and resources such that projects of a higher caliber are able to afford (7).

In an ideal situation the initial planning of scope, time, and budget will be constant throughout the lifecycle of a project. However, since this is not the case in the real world, risks and uncertainties may result in the shift of the original plan. One of the main contributing factors to this is improper cost estimation. An incorrect assessment of resources will contribute to the risks of overbudgeting. Therefore, better implementation of cost estimate in the earlier stages will result in better project performance.

In this thesis, the focus is on the optimization of the cost estimation in the planning stage of the project life. An in-depth research will be made to determine how this might be achieved through analyzing the existing literature concerning project management, risk, and cost estimation. Also, practical information will be gathered through the case study with data analysis and interviews and questionnaires with the professionals involved. Lastly, the case study is that of a project management company that works in the construction industry. Thus, the main focus of this thesis, or the conclusions and recommendations made as a result will also focus on the construction industry of USA.

Aim & Objectives

The aim of this thesis is to research methods of cost estimation and possibilities to improve this to minimize risk in the process and lead to a successful project completion. To achieve this, the following objectives are to be completed:

1. Study the existing knowledge of project & project management
2. Research what is risk and its effects on project success
3. Research into methods of project cost estimation
4. Analyze and compare data provided from case study
5. Draw a conclusion to optimization of cost estimation and provide future recommendations

Scope and Limitations of the thesis

The main objective of this thesis is to assess the properties of cost estimation and risk from existing data and formulate a conclusion about the correlations between the two. Furthermore, it aims to determine the optimal approach of formulating cost estimations in the initial stages of a project. While budget control in the later stages of the project life cycle is just as important for a successful project, these will be excluded. Since the thesis is constrained to limited resources, analyzing these parameters to the full extent of the project life cycle will be too broad. Thus, the scope of the research is the planning stage of construction projects.

Similar to the constraints of time, budget, and quality of projects, this thesis, being a project itself, was limited through the same constraints. The most significant of these being time. Furthermore, the current state of the world at the moment of writing this thesis in itself is a major constraint. Currently the world is plagued by the COVID-19 pandemic. This limits availability of direct access to our university's resources, at least in a physical manner.

Literature review

Project and Project Management

Introduction

Since the beginning of human civilization there has always been a demand for managerial positions in the social hierarchy (8). While early civilizations might have started out with small projects, tangible remnants of large-scale ancient projects can be found as early as the Neolithic period. The most well-known being the pyramids of Egypt which were built around 2500 BC. However, these activities of management were associated within the larger concept engineering throughout most of history. It wasn't until the 1960s when professionals started to look at project & project management as a separate field of study. Due to the growing popularity of the subject, various studies and publishing were made. One of the first was the formation of the triangular correlation of time, cost, and quality by Dr. Martin Barnes in 1969 (9). Subsequently, the application of projects has become so popular that they are practically used in most industries and fields including energy, health, construction, finance, military, and etc. The main function of a project is to provide organizations with a means of achieving their short term and long-term strategies (10). Furthermore, the development of projects has created the need for professional bodies that govern the standardization of rules and regulations. The largest of these are the Project Management Institute (PMI) in the US, Association of Project Management in the UK, and the collective entity of Project Management Bodies of Knowledge (PMBok).

What is a Project?

With the ever-increasing speed of technological advancement and worldwide competition, modern businesses have as many opportunities as they have threats. To keep up with the competition, organizations must constantly evolve and introduce new concepts to, at the very least, retain their current position. For example: a new product/service, improving their supply-chain, a new marketing strategy, etc. There are many different approaches to introducing this new idea, but the overall process remains the same throughout. Consequently, the notion of project and project management is created. In its essence, a project is a tool or mechanism

entities use to meet their long-term goals and strategies. Over the past half century, the concept of the project has evolved and become an independent field of study (8). Although all projects serve the same purpose, various scholars, researchers, and professionals have provided their unique definition of the term. Some of these definitions include:

- “an individual or collaborative enterprise that is carefully planned to achieve a particular aim” (11)
- “a complex effort, usually less than three years in duration, made up by various functional organizations, with well-defined objectives, schedule and budget” (12)
- “a unique process, consisting of a set of coordinated and controlled activities with start and finish dates, undertaken to achieve an objective conforming to specific requirements, including constraints of time, cost and resources” (13)
- “a complex, non-routine, one-time effort limited by time, budget, resources and performance specifications designed to meet customer needs” (3)

From these and more definitions we can see that there are common properties that are used to define what a project is:

- A project is a temporary endeavor meaning that all projects are bound within a timeframe with a beginning and an end
- All projects possess an objective or aim to be fulfilled at the end of completion, this aim serves as the main driving force for the project
- A project is limited in resources such as time, budget, and human resource
- A project brings added value or change that is the result of the project and what is left behind once it is finished
- All projects are unique due to the complex nature of its processes. Projects might be similar to one another, but in relative terms there will always be a difference in some way

Being a temporary endeavor with a beginning and an end, the timeline to which a project is subjected to is called the project lifecycle. For better understanding and defining the sub processes a project contains, the lifecycle is divided into five primary steps. These are: initiation, planning, execution, control/monitoring, and termination. It should be noted that various resources present different interpretations of the project lifecycle, so there are cases with 6 steps or with 4 steps. Common textbooks such as “PMBOK” by the Project Management Institute or “Project

Management: The Managerial Process" by Gray & Larson have 4 primary steps with the removal of control/monitoring. However, within the context of this thesis, the 5-step guide developed by the Industrial Engineering faculty of GMIT has been chosen. A proper understanding of the project life cycle can enable a project manager to correctly distribute resources and attention to the right activities and allow for a smoother process during the course of the project. The typical amount of activation in each step is represented by the following figure 1.

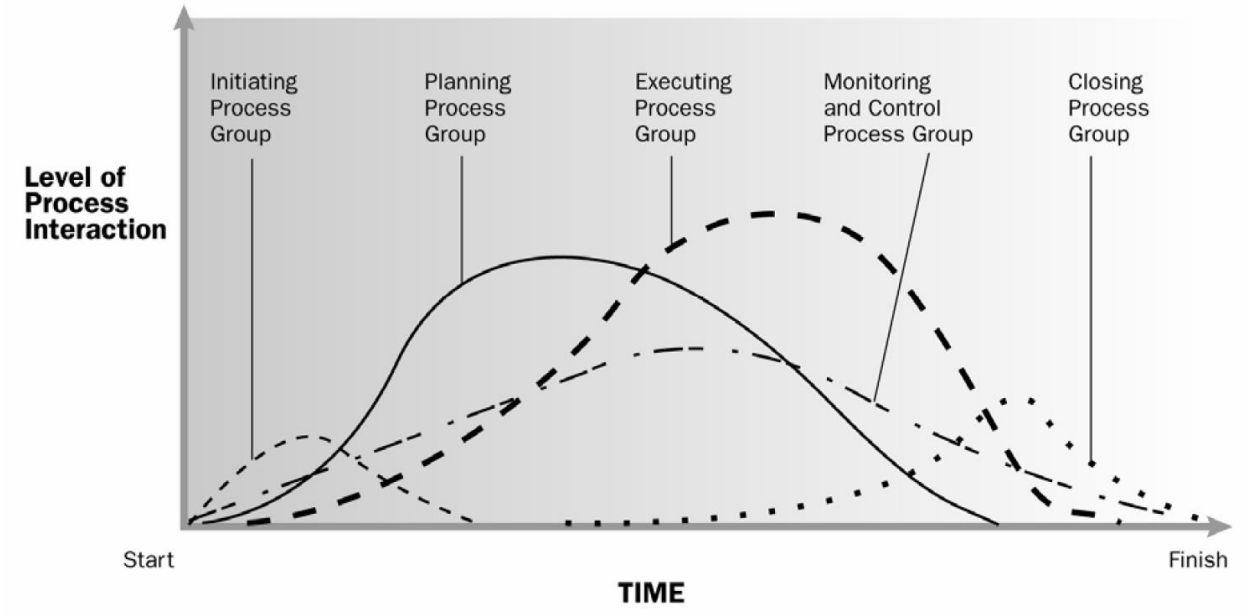

Figure 1: Activation of Project Lifecycle

To explain the 5 stages in further detail:

1. Initiation/Ideation - the initial creation of the project as a concept. This step includes development of the goal, scope, and timeframe of the project. Due to the lack of information this step has a high level of uncertainty.
2. Planning - during this stage detailed plans such as the schedule, technical specifications, and budget are made. The workflow is broken down and proper assignment of project team members are carried out.
3. Execution - in this phase all of the previous planning is set into motion. This is the step which requires the most amount of attention and resources from all of the steps.
4. Control/Monitoring - during this step the activities carried out in the execution phase are monitored and adjustments are made if necessary.

5. Termination - once the project is completed and it has met the initial objectives, a closing step will take place where the product of the project is passed onto the customer and documentation of the project is archived.

Project Management

With the right definition, any endeavor or act with a purpose can be seen as a project. Consequently, there have always been individuals and groups who managed these projects throughout history. However, it wasn't until the last half century when it became a concrete term (8). As more organizations and entities started to use the mechanisms offered by implementing projects, various studies and institutes dedicated to the study of project and project management came to be. The largest of these are the America's Project Management Institute (PMI) and the UK's Association of Project Management (APM), established 1969 and 1972 respectively (14).

The following is a definition for project management as offered by the PMI: "the application of knowledge, skills, tools and techniques to project activities to meet project requirements. Project management is accomplished through the application and integration of project management processes of initiating, planning, executing, monitoring and controlling, and closing. The project manager is the person responsible for accomplishing the project objectives." Project management is a collective effort made by the project management team which consists of individuals with a broad field of knowledge and capabilities to offer but are all focused on a common goal (15). An important aspect of project management is communication. Not only internal communication between the members of the project management team, but also external communication between the customer and project management team. This is important especially in the initial stages because the lack of proper communication will result in a misunderstanding of the goal and objectives of the project. Consequently, the end product will not meet the customer's expectations (8).

As project management moves into the new century factors such as rapid technological advancement, globalization, and stiff competition have created incentives for companies and organizations to constantly evolve and create new products or services to fulfill the ever-increasing demand from the customers (16). Naturally, through effective implementation of project management entities are able to fulfill this demand of high-quality products or services for the cheapest possible price. Furthermore, the life cycle of projects has decreased notably in recent

years due to the development of dedicated software (17). As a result, this adds to the importance of effectively utilizing project management in companies' strategy to retain their competitive advantage.

Risk and Risk Management in Projects

What is Risk?

Most people define and associate risk to be an action that may possibly lead to a negative consequence. Although this assumption might suffice in everyday activities, in the project management world risk is defined as "an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives" (15). Due to the arbitrary nature of risk it is optimal for project management to control it to their extent for a successful project.

When talking about risk another similar key term needs to be mentioned. This is the concept of uncertainty. Although they are often used interchangeably, even in professional fields such as finance and management, they are different concepts (18). An easy way of understanding these concepts is through the figure 2.

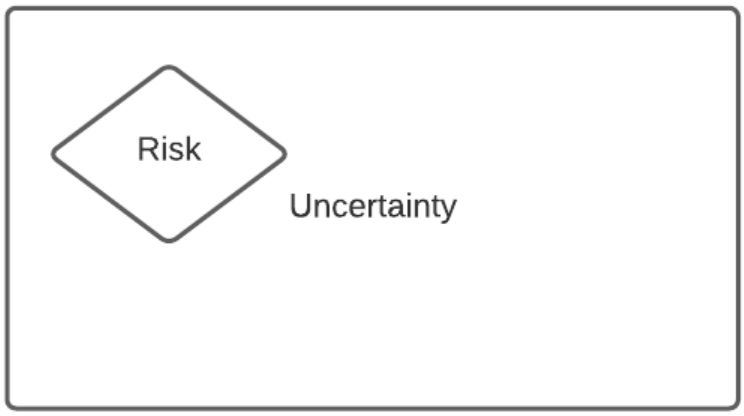

Figure 2: Risk & Uncertainty

By analyzing the figure, it can be seen that risk is a part of uncertainty. In other words, uncertainty can exist without risk while risk cannot exist without uncertainty. From various definitions made about risk and uncertainty the following definitions have been derived.

- Risk - a circumstance in which the possible outcomes are known to some extent and can be quantified in terms of its probability of occurrence to a reasonable degree
- Uncertainty - a circumstance where there is absence of knowledge with regards to the possible outcomes and cannot be quantified

To put in simple terms, risk a quantifiable concept that can be evaluated with statistical assessment of hard data. On the other hand, uncertainty is a non-quantifiable concept that can only be theorized through subjective probability using only informed opinions (19). Consequently, it is safe to assume that every construction project, or project in general, possesses a degree of uncertainty. The existence of risk on the other hand is more circumstantial.

As we discussed earlier, the term risk has a broader meaning than the one used in everyday communication. It can mean a positive or a negative influence on the project. Which becomes important in the context of project management. The reason being that although our main priority is to mitigate the negative consequences of risk by identifying it before it happens, it could also be that opportunities have risen as a result. When such an opportunity is presented a project manager must be quick to act upon it.

Types of Risk

Risk in a project can take place in a variety of areas. This can include scheduling, budgeting, funding, resource management, communication, work of third parties, etc. Thus, there exists added benefits by analyzing and categorizing risk. The PMI has created the following categorization that can be seen in table 1.

Table 1: Types of Risk

Risk type	Definition	Example
Known risk	that which is clear and no uncertainty exist	failure of finished project to meet its specification in case of negative risk or budget underun at end of project for positive risk.
Known-Unknown risk	that one is aware of but do not know how they will affect or influence the project	Concrete mixers that will at some time require maintenance.
Unknown-Unknown risk	that one cannot imagine and therefore, have no awareness of	a sudden employee's illness that may disrupt the workforce and result in a lot of time-off at same time

From the three different types of risk, the last or unknown-unknown risk possesses the greatest impact and is the most difficult to prevent. Thus, to formulate an accurate estimate of the cost greater emphasis must be placed on the unknown-unknown risk. However, this does not mean to exclude the first two types (20).

Risk Management of Projects

The risk management process has become a general practice for companies of any size and type in modern business. So much so that risk management standards have been published to meet interest spawned by project management associations, government agencies, and business corporations. Some of these include the UK's Turnbull report and the USA's Sarbanes-Oxley report (21).

The risk management process should be properly structured and then maintained in order for it to be properly implemented. Especially considering many cases from the past where a company has introduced risk management without maintaining focus on the application in practice led to failure of the project (2). Overall, risk management is a scalable activity that is applied in order to

meet the project objectives in an interactive and integrative way. Assessing risk is an important portion of this process and can be completed using various methods and tools. Commonly used are risk questionnaires, risk surveys, SWOT analysis, facilitated workshops, Monte-Carlo simulation, scenario analysis, decision tree analysis, utility theory, and brainstorming.

Risk in Construction

Construction projects are exposed to risk just like any other type of project. This risk stretches along the full length of the risk spectrum in terms of type and amount. Risks in construction can be specific to each individual project as factors such as location, weather, season, and economy play a vital role. Like other projects, the risk assessment of a project should be active throughout the whole life cycle of the project and encompass the efforts of all the individuals and departments on the project. The following areas of construction risk have been addressed as general types of risks that may occur (22):

- Technical Risk
    - Incomplete Design
    - Inadequate site investigation
    - Availability of materials
- Logistical Risk
    - Availability of transportation methods
    - Availability of facilities
- Construction Risk
    - Uncertain productivity of resources
    - Weather and seasonal implications
    - Industrial relations problems
- Financial Risk
    - Inflation
    - Fluctuation of foreign exchange
    - Repatriation of funds
    - Delay in payment
- Political Risk
    - Difficulties in disposing of plants and equipment
    - Insistence and use of local firms and agents

Project Cost Estimation

Introduction

For a realistic and reasonable budget, the cost estimation process should be carried out in full, with appropriate tools and techniques, considering all factors that could affect its accuracy and reliability (7). Cost estimates help top decision-making management and enable project managers and project teams to plan project budgets using a monitoring and tracking tool as the project progresses (6). Top management (top-down approach) or project manager (bottom-up approach) may enforce project budgets, but in the construction industry, the former is the most common practice as projects are managed by sponsors or funders. The cost estimating process must be controlled for reasonable project budgets, and correct methods must be used. Among them, a number of factors affect the quality of project estimates include experience and efficiency of estimators, project design, task specifications, assigned time frame and etc.

What is Cost?

In simple terms cost is the amount to be paid or spent in order to obtain or buy something. However, the processes and steps of a project create different classifications and types of costs. Classifications include fixed and variable costs, recurring and nonrecurring costs, and direct and indirect costs. Fixed costs are those that are to be paid regularly in a standard period of time such as rent and maintenance staff salaries. On the other hand, variable costs are those that depend on dynamically changing factors such as production volume and labor activity. Raw materials and salaries of production workers are examples of variable costs. The concept of economies of scale can be understood by understanding fixed and variable costs. As volume of production increases variable cost increases proportionally while the fixed costs stay static. Consequently, the unit price of the product is lowered. These costs play an important role in analyzing cost behavior. Recurring and nonrecurring costs differentiate between costs that have to be paid repeatedly over the duration of a project (such as raw materials and salaries) and single payments. Lastly, direct and indirect costs identify if the incurring cost is directly attributed to the product or not. For example, cost of raw materials, salaries of workers who make the product, and cost of tools and equipment used to make the product are considered to be direct costs. In contrast, examples of indirect costs include salaries of administrative staff, transportation costs, and cost to maintain or fix equipment.

The different classifications are necessary for various reasons. A better and more systematic approach of following the costs throughout a project can be achieved by correctly classifying the costs. Moreover, these classifications are important in being used to price the offers. To conduct a pricing of the offering the total cost of the product is calculated by combining the indirect and direct costs. However, it should be mentioned that companies can have their own unique approach to making this calculation. Furthermore, once the total cost of a product is completed an additional profit margin is added on to create the final price. This method of allocating indirect expenses similarly between the products is known as contribution costing. While some cost systems use the direct costs as a base to proportionally calculate the indirect fixed costs, others use cost drivers to assign costs (23). A cost driver is a terminology used to define and quantify the cost creating factors of an operation. This is a relative term that changes depending on the nature of the operation or business. For a mine this could be kilograms of product produced, whereas in a fast food restaurant it could be the number of burgers sold. Since this term is relative, it is important to choose the correct cost driver for each operation.

Purchasing or spending to obtain assets is a commonly occurring process in organizations. While this process may seem like a straightforward transaction, in the context of a project, cost incurrence is a process consisting of several intermediate steps. A typical procedure starts with the cost planning, goes through internal and external cost commitment, followed by resource acquisition and resource consumption, and finally ends with payment (24). The cost planning is a stage where the cost structure of the organization is created by comparing available resources. In other words, it is the approach of the organization as to how they are going to create profit by delivering value to the customers. This stage is significantly important due to the fact that decisions made in the cost planning phase have the highest impact on the cost incurrence process. Making changes to the process design after the initial phase becomes increasingly harder and resource consuming. This relative notion of a project's life cycle and importance of decision influencing costs can be seen from figure 3.

By analyzing the figure, we can see that affecting the project cost decreases significantly with the beginning of implementation. Also, the cost and difficulty of making change increases inversely.

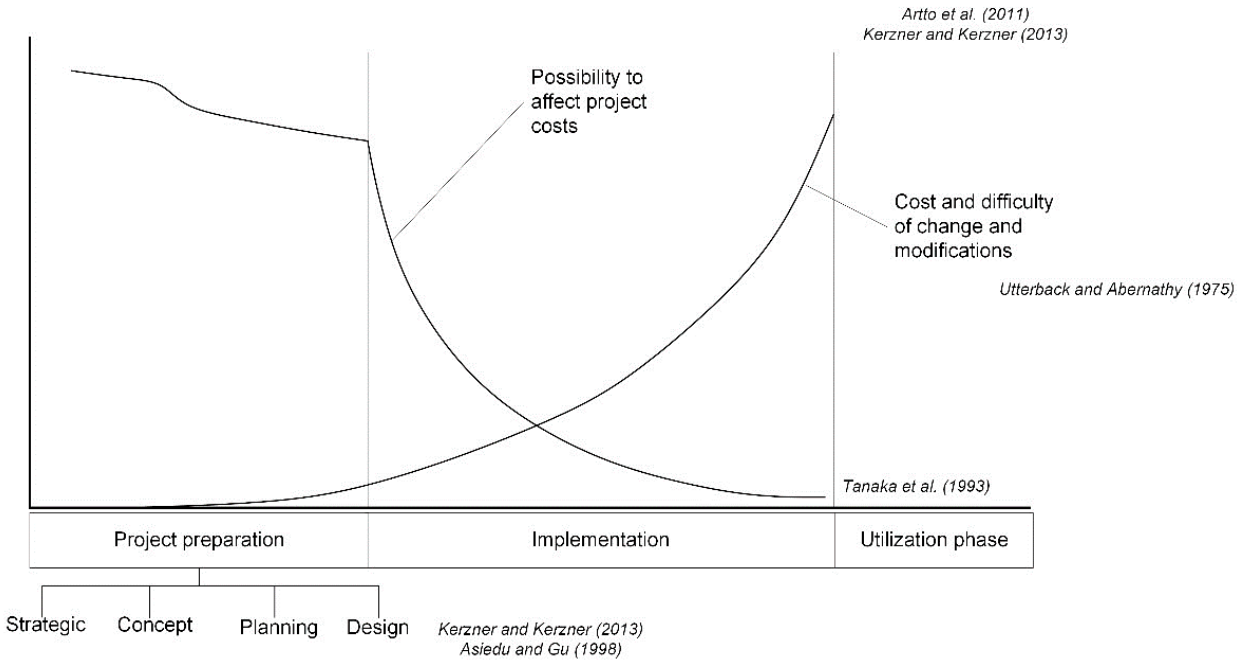

Figure 3: Cost during Project Lifecycle

Internal and external commitment are the following steps of the cost incurrence process. The commitment processes involve researching the status of the organization to conclude whether or not to commit to the cost incurrence and then to contact external sources. In other words, the internal commitment stage is when authorization of a project's budget is given. In most cases this is executed in the project preparation phase through the audits made during the sales process. Once the decision has been made internally, the next step is the external commitment process where contacts are made with external entities to place orders or hire contractors. After this stage the cost incurrence process cannot be reversed.

Resource acquisition is the stage of obtaining the previously made orders. These orders can be in the form of tangible objects or services. After this stage the resource consumption takes place. As the name suggests, it is the stage where the obtained resources are utilized to fulfill the initial need.

The last stage is that of payment. Here the realization of all the planning made during the previous steps takes place in the form of physical payment. For most projects this payment is completed in a series of stages. While actual payment plans vary depending on unique circumstances of projects, common stages include the advance payment, milestone payment, and the final

payment. The schedule to which the payments are made is agreed upon by the supplier and customer in contracts made prior. It should be mentioned that the process of committing to a cost precedes the actual cost in practice. The reason being that projects allocate majority of their capital resources in the planning stages and commit to it before purchasing items or services in the execution phase.

Cost Management in Projects

Cost management is a process which is used to guarantee outcome of a project to satisfy the financial targets set in place (25). Ultimately it serves to increase the cost efficiency of a project through means of activities and decisions. Furthermore, it is an ongoing process that is refined with every stage of the project life cycle. As stated in the PMBOK by PMI, the primary components of cost estimation include resource planning, cost estimation, budgeting, and cost control (figure 4). However, there can be more components depending on the particular project or field.

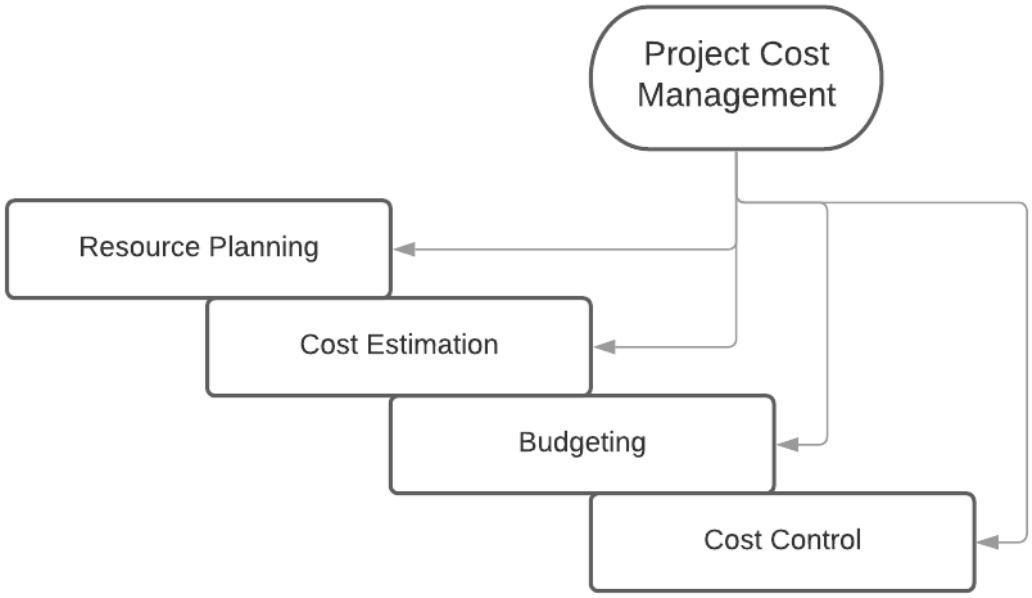

Figure 4: Components of Project Cost Management

Resource planning is used to identify the resource requirements that are needed in order to achieve project goals. Existing data such as WBS, historical information, organizational policies,

scope, resource pool, and duration estimates are utilized to create the resource requirements (15). Similarly, the cost estimating process uses that same sources of data with additional information such as staff wage, activity duration, risk identification, and cost account structure to produce a quantitative valuation of costs. This estimation is important as it is used in later pricing, bidding, and negotiations. The next process of cost budgeting allows for allocation of the previously made cost estimates to activities and work packages to create the cost baseline of a project (15). Lastly, the cost control process is involved in monitoring and managing changes to the baseline cost as various factors change throughout the project lifecycle (26). Looking at the components, it is clear that they are interconnected processes and the information gathered throughout cost management is valuable in future budgeting and cost estimation.

For cost management to be effective the existence of accurate and relevant information that can be accessed easily is essential. Furthermore, the process should be formalized and standardized to be an integral part of the organization where all departments contribute and recognize its importance. As the cost management process is key to the overall project management and is active during the whole project lifecycle, it serves a pivotal role in project success. Moreover, it works in unison with other aspects of the project management process such as schedule management and resource management (27).

Widely used methods in cost management include Design to Cost (DTC) and Target cost Management (TCM). While these methods are both viable options for cost management, they use different methods to accomplish their goals. The DTC focuses on setting the cost as an internal parameter to the design process of the project. This method allows for the cost to be treated as an economic internal constraint, which leads to a more efficient cost control during planning and design phases (24). On the other hand, TCM is a reverse costing method, which first sets up an estimated target cost and only allows a product to be produced when its lifecycle cost is proven to be lower (28). Thus, the primary difference between these two methods is that DTC considers cost from an internal perspective, whereas TCM proceeds from an external perspective.

Cost Estimation

Cost estimation is a process of analyzing existing data through various quantitative models to produce estimates of future costs. Because cost estimation is defined as a forecasting method, it differentiates from cost analysis, which is focused on organizing and processing historical data

(29). Activities such as bidding, negotiations, cost tracking, and cost analysis benefit greatly from properly executed cost estimation.

In a cost estimation, there are two primary classifications the necessary data can be divided into: historical data and organizational operations. Historical data is any data that has been accumulated through previous operations regarding cost estimates, statistics, and published reports about similar work from external or internal sources. In most cases, expansive information about a company's financial records are hard to come by. Alternatively, scientific researched concerning various fields and their best available practices can be used as a guide. However, unprocessed information alone is not enough to make cost estimates. The existing data must always be analyzed and systemized in prior step of cost analysis (15).

As stated by authors Steward and Wyskida (1987), there are inputs which must be provided for a complete cost estimate. These are: information, methods, plans for the estimation process, and the skills that are necessary. Furthermore, a twelve-step process which uses these required inputs for successful cost estimates was created. This process can be seen in the figure 5.

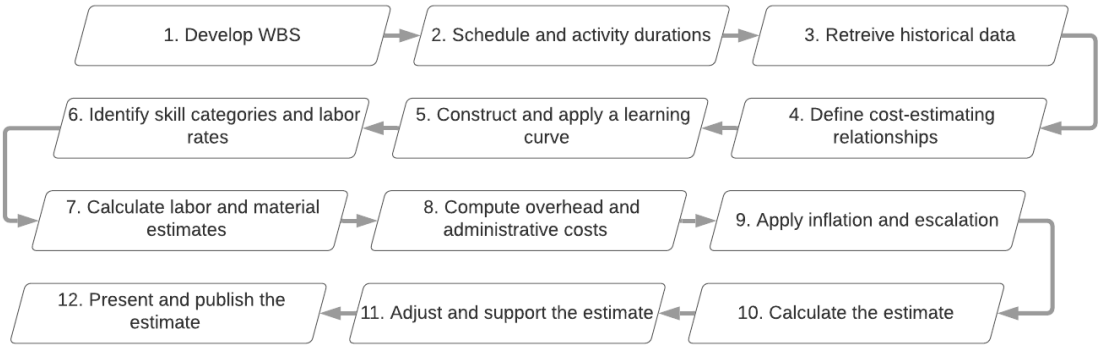

Figure 5: Twelve-step process for cost estimation

Illustrated by this figure, the cost estimation process is focused on the type of data needed and actions to take by adjusting and supporting the estimates and finally fabricating reports of the process for use in next phases and future references as well. As mentioned before, the cost estimation process is an ongoing one. As new information is gathered and processed throughout the cost estimation, adjustments will be continuously made. The final report is vital in the communication of information to the next steps. This will include the estimate, additional assumptions, and relevant remarks. While there are many different approaches of how this report

could be structured, in the following table 2, a possible solution created by Steward and Wyskida (1987) is shown.

Table 2: Content of Cost Estimate Report

	Title	*Content*
1	Introduction	Case with background information
2	Specifics	Ground rules and assumptions
3	Description of the work activity	Schedule, specifications, quantities, location and other applicable factors
4	Detailed cost breakdown	By work element, by cost element, by schedule element
5	Summary of the estimate	-
6	Pricing factors	Labor rates, inflation rates, material prices, overhead, fee rates
7	Estimating team details	Name and contact information
8	Rationale	Material backing up the cost estimate: an explanation of reasoning

In this approach, the report is separated into eight different parts that divide the information for easier understanding. However, this is just a recommended approach. At its core, an effective report must be clear and concise in the information it provides and provide as many case specific details as possible.

A second possible approach at the cost estimation process is provided by the Project Management Institute. Here the cost estimation process is divided into three phases: inputs, tools and techniques, and outputs. Figure 6 shows the process.

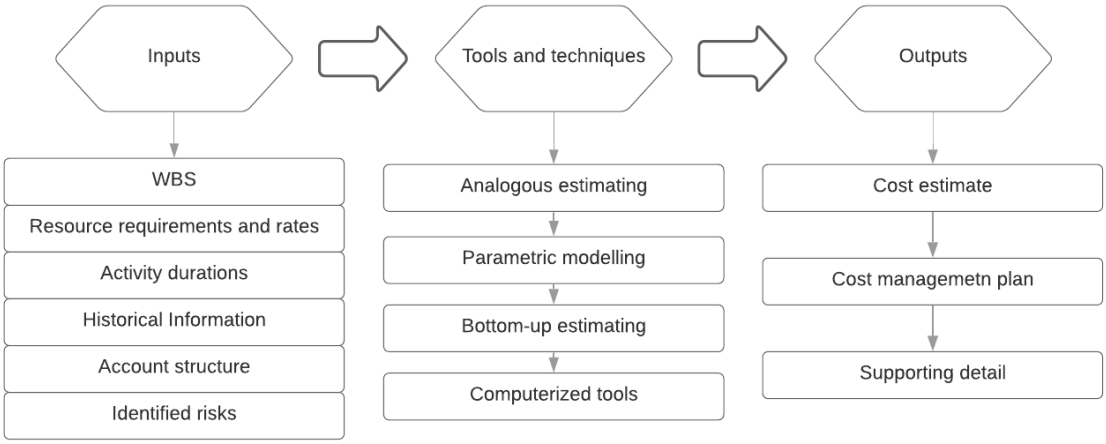

Figure 6: Cost Estimation Process

The cost estimation process shown in the figure defines the inputs necessary as the information requirements. Next, the cost estimation tools and techniques include analogous estimation, parametric modeling, bottom-up estimating, and computerized tools. Lastly, the output includes the quantitative figures of cost estimate, a plan to execute it, and various supporting details. The cost management plan is an action plan that utilizes the risk assessment to dictate how to manage the unforeseen circumstances in order to keep the costs within a desired amount. Additional supporting details include the pricing factors, established rules, and assumptions, description of the scope of the work as well as the range of the expected costs.

Looking at cost estimation processes from various sources, common qualities can be derived. These include the development of scope and technical specifications, pricing factors and information gathering of cost data, analysis of historical data, acknowledging assumptions made, selection of estimation method, risk assessment, creation of clear and concise documentation, and timely review and renewal of estimate. Furthermore, the iterative nature of cost estimation is emphasized in all references. The updated estimates are an effective and useful tool for the companies during the initial estimation phases, as the estimation calculation can be accelerated with the data collected from the previous equivalent projects (26).

For successful cost estimates, knowing what to do is not enough. The practitioners of the cost estimation process must be knowledgeable in areas of engineering, statistics, mathematics, production planning, communication, writing, and industrial engineering. Additionally, the cost estimator must understand the organization’s operations and have experience in the industry (30).

However, in practice, it is hard to find individuals who possess all these qualities simultaneously. Thus, organizations sometimes approach the cost estimation process with a team of individuals skilled in various fields. In the case that a team or department for the cost estimation is not available, direct communication and relationships between the cost estimator and operational departments responsible for work packages and contractors needs to be established. Lastly, historical information can be used effectively in cost management. However, organizations must keep a well-documented, processed, and easily accessible database to provide historical information (26).

Techniques of Cost Estimation

Cost estimation techniques can be divided into two categories of quantitative and qualitative. Quantitative techniques include parametric and analytical cost estimation. Statistical and functional estimations are examples of parametric techniques. Analytical quantitative estimates are represented by top-down and bottom-up cost estimation methods as well as deterministic approaches. These techniques use some level of mathematical analysis to perform the cost estimates. On the other hand, techniques such as intuitive and analogical are qualitative. Guesstimation and expert opinions are considered to be intuitive qualitative estimation techniques. Analogous and project comparison estimating are examples of analogical techniques. In the following table 3, common techniques of cost estimation are presented.

Table 3: Cost estimation methods

	Technique
1	Analogous estimating / project comparison estimating
2	Detailed cost estimating / bottom-up estimation
3	Parametric modeling
4	Computerized tools
5	Assembly estimating
6	Expert opinion / guesstimation
7	Learning curves and progress functions
8	Design to cost / top-down estimation
9	Deterministic / risk based - Monte Carlo simulation - Three-point estimation

From the techniques presented in the table, the most commonly practiced were analogous estimating, detailed cost estimating, and parametric cost modeling. Analogous cost estimating is

a method which uses existing information or historical data of similar projects completed in the past to estimate the costs, especially is there is a lack of information about current project. The existing information is scaled to the dimensions of the current project using methods such as six-tenth rule. This is usually a method that is used in the beginning of cost estimates, as it requires relatively low amount of resources and the cost estimation is less accurate.

Detailed cost estimation is a method which focuses on the work packages on the most detailed level possible. For this estimate, specifications of scope and schedule need to be carried out to a full degree for precise results. Also, this estimation method requires the most amount of resources. The parametric modeling, on the other hand, is a method which uses mathematical functions to predict the project costs. Certain parametric inputs such as area or height can be used to portray the scope and cost of the project. As stated in the PMBOK by PMI, “accuracy of the parametric estimate is dependent on the availability and relevance of the available historical cost data used for parametric input, scalability of the model and whether the parameters are quantifiable.”

Various types of project management software, spreadsheets, and statistical tools are used as computerized tools. Software can be extremely useful and resource effective because they can perform high levels of computation in a quick duration. Two key elements of the software are the database it has access to and the computational algorithm it uses. While it is possible that software might replace the cost estimation process in its entirety in the future, in current practice, computational programs are used as supporting tools to the common methods mentioned above. This means that currently more significance is given to the database aspect of the software.

Assembly estimation is a technique that uses the bid for a work module to compute the cost estimate. The bid consists of the material and labor costs combined. This method is common in construction projects. Guesstimation or expert opinion can be very useful in the early stages of the project planning. This is because expert opinion can be performed easily with light resource consumption. However, this also means that the accuracy of expert opinion tends to be the lowest. DTC is a product development tool that can also be used within the context of cost estimation. The basic idea, as described before, is to set a target cost based on the existing market and plan out the activities and work packages within the set limits. This is also referred to as the top-down approach.

The deterministic technique uses inputs of all likely risk factors to set up a proper contingency. This method is also known as the risk-based approach. Unfortunately, this method is only better suited to small scale projects due to increase in inaccuracy as the complexity of the project becomes greater. Within the risk-based technique there are few different approaches that can be taken. One is the Monte Carlo simulation. The Monte Carlo simulation is a common tool used in quantifying probabilities with complex structure and multiple factors. It is commonly used in cost estimation and risk assessment processes. For this method to be accurate, it needs large database of historical and current information. Another approach used in the deterministic technique is that of three-point simulation. This method uses three values of minimum, most likely, and maximum with their respective probability to calculate an expected value. The type of distribution model selected changes the outcome.

In most cases, a combination of multiple different techniques is implemented to achieve a final result. This is in one part due to the continuous nature of project cost estimation during the project lifecycle. In the beginning of a project, when there aren't a lot of information available, methods such as expert opinion might be useful to quickly set a general idea of how much the cost estimate would be. As the project progresses and more information about the project is made clear then more complex methods such as detailed cost estimate is used.

Budgeting

Budgeting is the next course of action after cost estimation. By taking the individual cost estimations into account, a set amount of total possible expenditure is created for the project. While the two terms are almost identical in the information they convey, there are some differences. The most notable being the distinction that is made during the transition from planning to execution. When the customer makes a legal contract about the budget of the project, the budget serves as a static restriction or reminder of how much can be spent and the project works to stay within this guideline. On the other hand, the cost estimation is a projection of cost of the project as it progresses. Thus, it must continually evolve and change (15).

Aside from the cost of the activity and work package, the budget includes additional costs. The cost of contingency and the management reserves are estimated to cover the costs in the case of undetermined or unexpected factors. The contingency reserve is created to protect the project from potential risk identified during the risk analysis. The management reserve on the other hand is made as a reserve to be used in the case of unplanned work arises. In other words, contingency

reserve is for known-unknown risk and management reserve is for the unknown-unknown risk (15).

Contingency is defined as a monetary sum added to the estimate to cover the consequences of risk events in case of them materializing. By calculating the probability of potential risk factors, a quantified measure of contingency is produced. Contingency reserves not only take into account the risk to budget but that of schedule as well. An example case of program evaluation review technique used to calculate the contingency reserve is given in figure 7.

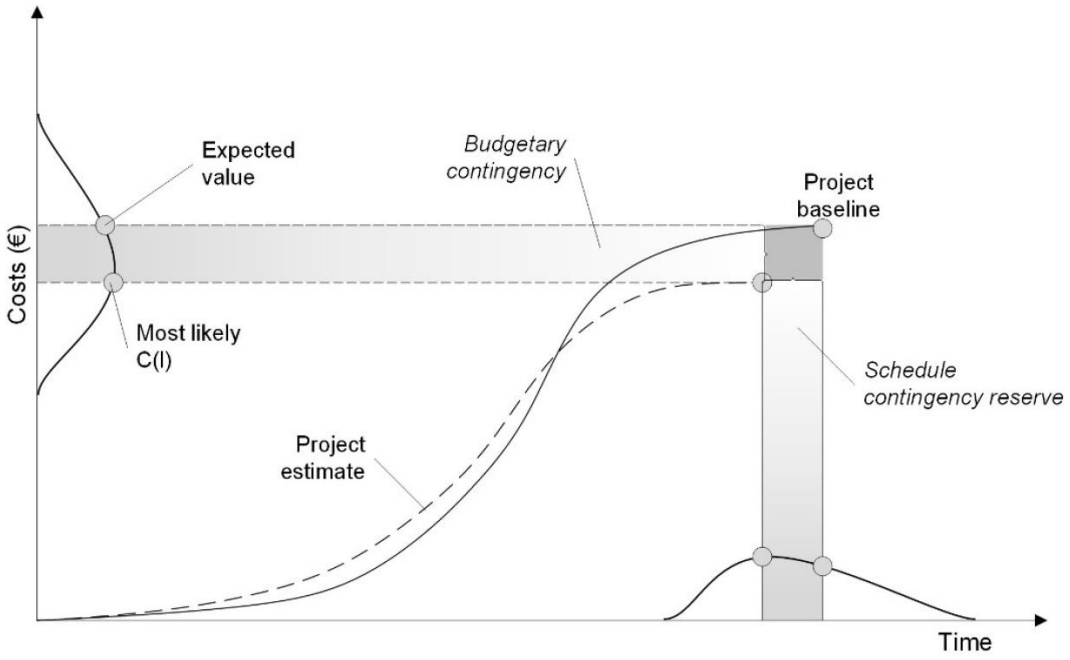

Figure 7: Project estimate vs baseline

Here the project baseline is set by adding the budget contingency and schedule contingency on the project estimate. Commonly the management contingency is added to the baseline to produce the project's budget.

Methodology

Research Approach

There are two research approaches that are accepted and used by professionals; deductive and inductive approaches. These two methods differ on how the concept is evaluated in the research. Deductive approach is based on analyzing existing theories and then testing it in practicality to approach a final confirmation of a hypothesis. On the other hand, Inductive research is the opposite. It is performed by first taking an observation and then formulating a theory based on the empirical data (31).

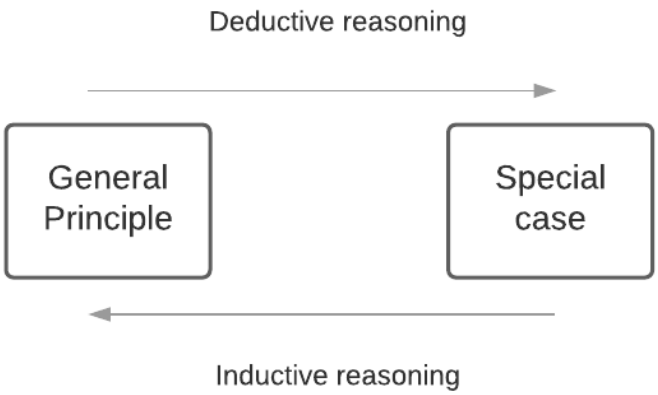

Figure 8: Research approach types

Within this thesis, the inductive research approach was chosen. While limitations of this research have made formulation of primary data difficult, the author was fortunate enough to retrieve data from case company. However, the data provided was not sufficient by itself. A combination of secondary and primary data was used with emphases on the primary data. First careful inspection of current theories on cost optimization and risk assessment was conducted. Then the data from the Square One case study was used to analyze the theories and create a conclusion to the observations.

Research Strategy

The research strategy aims to clarify the distinction between how the data collection process is made. There are three main types of strategy; qualitative, quantitative, and mixed or integrated approach (32).

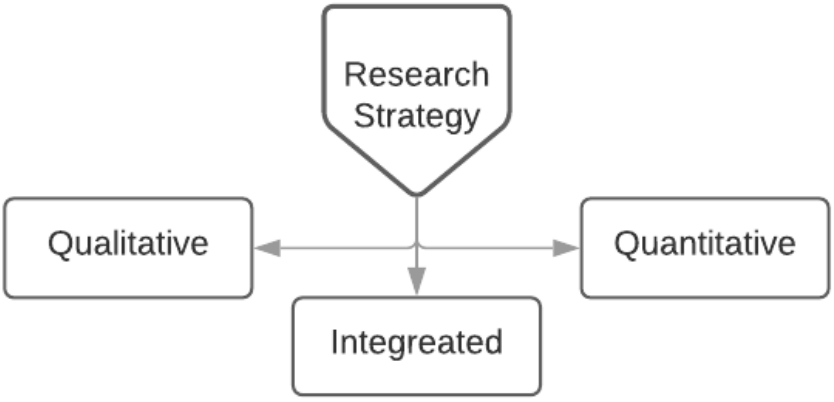

Figure 9: Research strategy types

As the name suggests, a qualitative study is focused on the perceptive information and understanding that is provided by informants on a particular subject. Such methods include face to face interviews, focus groups, and case studies. While a qualitative method is advantageous in sharing in depth knowledge, it is not always preferable due to high investment of time and focus. Also, the information is subjective, thus impermeable to biases from the informants. On the other hand, the quantitative method is focused on the information provided by statistical data. The most common way to collect quantitative data is to conduct surveys. It should be noted that the statistical data does not have to be purely numerical (33). Lastly, the integrated approach utilizes both qualitative and quantitative strategies. More researchers are using this approach due to the availability and better overall performance. Due to the previously mentioned reasons the integrated approach is superior if implemented right. Thus, for this thesis the integrated method is chosen.

Research Method

The smallest unit in determining the methodology is the research method. Examples of research methods include; experiments, survey, interview, action research, and case study. The type of method is dependent on the context and circumstance of the individual research. As the title

suggests the main method selected in this thesis is that of a case study. In a case study, real-life events are analyzed to produce conclusions and recommendations. This is a suitable method when there is little control over the event under study (33). Therefore, being a case study, real life examples provided by the Square One consulting company will be used in this research to fabricate a conclusion to the problem of cost optimization and risk management. Furthermore, an additional method of survey will also be implemented to enhance the outcome.

Data Collection

The data in a research can be either primary or secondary. Primary research is when data is collected through observational methods such as survey, experiments, and case study. On the other hand, secondary research is when existing research materials surrounding the subject of choice are evaluated to produce a conclusion.

For this thesis primary research was implemented. Data for the case study was provided as information on previous projects handled by Square One Consulting. Furthermore, multiple interviews with the CEO of the company, chief cost estimator, and project manager were conducted to understand the processes of the company and retrieve information on project management and cost estimation.

Lastly, an online survey was sent out to the members of the company to compute the issues of cost estimation within project management. The survey consisted of a mix of open and closed questions. The open-ended questions were targeted at betting basic information of the participant such as working experience and educational degree. The closed ended questions consisted of various statements and the degree to which the participant agreed to the statement. The statements were primarily about the cost estimation practice and where potential setbacks or difficulties exist. The response rate of the survey was 36% from a pool of 25 potential participants. The survey is presented in full in the appendix section.

Case Study

Introduction

A case study is a common research method which involves analyzing a real-world example or case study and forming conclusions or recommendations to support an overall statement. For the context of this thesis, the primary objective was to research into the cost estimation process of projects within the construction industry. To accomplish this, Square One, a project management consulting firm, was contacted to become a part of the thesis and provide information about their approaches and practices of project management in the construction industry to be studied within this thesis. Also, methods such as survey and interviews were implemented for research. An investigation into the processes of project management and cost estimation at Square One is presented in this chapter.

Square One

Square One is a Native American owned, full-service Owner's Representation firm. The firm was founded and has been in business since 1995. Square One offers expertise and experience in construction and project management. Individual projects can include but are not limited to casino and hospitality, hotels, data centers, and control centers, Class A high rise office buildings, corporate facilities, retail centers, condominiums, churches, K-12 schools, and higher education. Some high-profile clients include Oracle and Dell. Currently they offer their services in projects located in 9 states of the US. This is shown in the following figure 10.

Figure 10: States Square One is active in

The Project Management team has over 800 years of combined experience in the industry and has managed $18 billion in construction projects. This experience provides owners the knowledge base to minimize any risks that arise during the different phases of design and construction. Square One's approach to projects focuses on the ability to provide Owner Representation through analysis and consultation for every aspect of the project, including land purchase, team structuring, planning, zoning, budgeting, designing, financing, coordinating, contractor selection, and more. Currently Square One has 25 professionals in project management that offer their services as project managers. As a part of their work they've assisted clients in securing services of design teams, architects, appraisers, surveyors, civil engineers, security personnel, roof consultants, and others.

Operations of Square One

Overview

All projects exist to fulfill an outcome. They achieve this in a step by step sequential manner that is known as the project lifecycle. The first stage is ideation or the creation of a project. While this step may seem like it serves little purpose, it is in fact quite contrary. Without this stage the project wouldn't exist at all. In the industry of construction, this step is fulfilled by the client of project management consulting firms. Once there is a client that wants a project, or in this case the construction of a building, the project management consulting firm steps in to carry out the project for the client. Thus, a generic overview of Square One's operations can be defined as completing a project on behalf of a client.

Square One is an Owner's Representation firm. This means that when a client wants a building and has the capital to construct said building, they contact Square One to become a representative of the client to carry out the project to fruition. Each project is defined by three parameters that are provided by the client: the scope, budget, and time (*figure 11*).

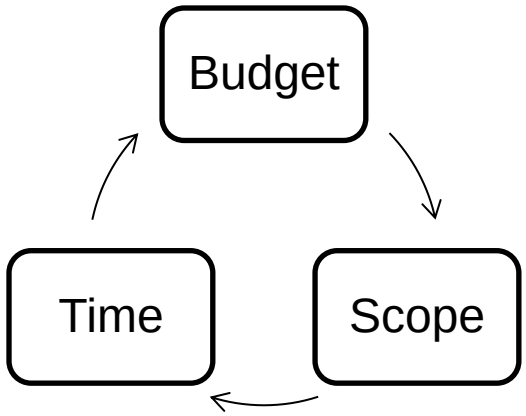

Figure 11: Triangular correlation of budget, scope, and time

Although, there will be changes to these parameters during the planning phase while negotiations between the firm and company are still ongoing. Once an agreement has been made it is Square One's obligation to complete the project within said limits while keeping in mind the client's best interest. Furthermore, projects require team efforts. Depending on the size and complexity of a project, there can be large number of departments and professionals working on a single project. As a project manager, the primary focus of Square One is to oversee and manage the work of professional personnel and entities involved in the project and maintain progress with the least amount of restriction.

Project Management

When a client approaches Square One with an idea, the company assigns one of their active project managers on the project. This project manager will then represent Square One until the completion of the project (exceptions to this might include a termination of project before completion due to unforeseen factors or changing of project manager by the Square One management). The following figure 12 shows the primary functions of a project manager working on a construction project.

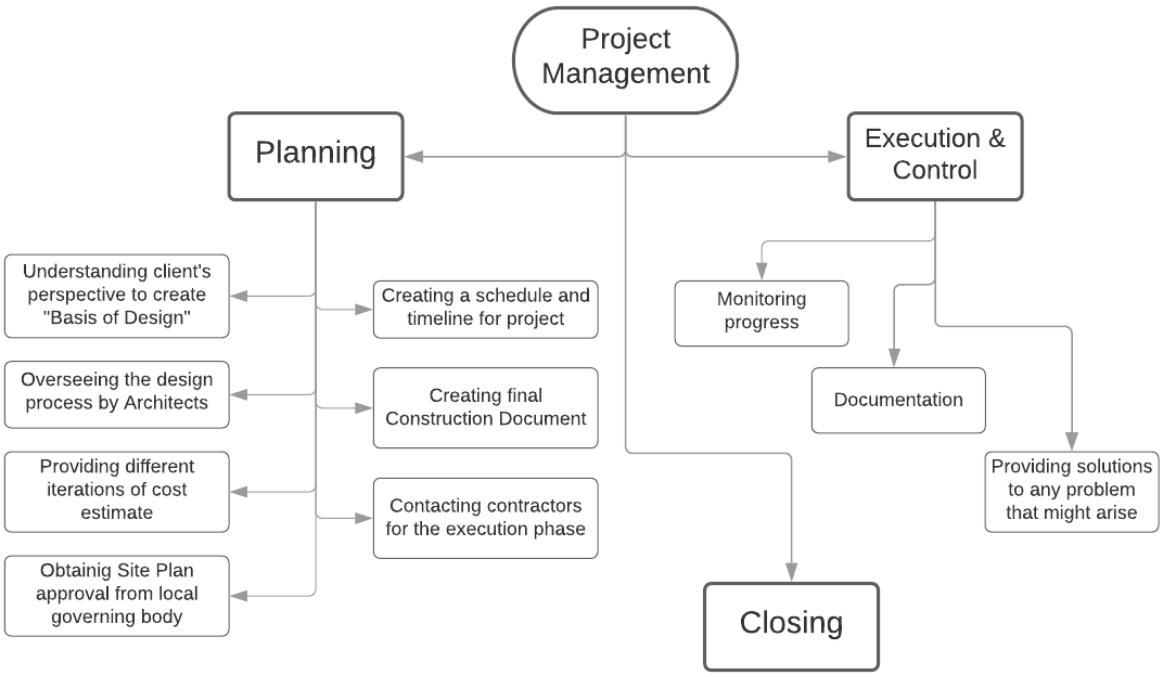

Figure 12: Activities of project manager

The figure is presented with the planning phase occupying the largest portion with the most activities. This is because this stage requires the most amount of input from the project manager. Taking into consideration that it is possible for complex projects to have multiple phases active at a given time, the general practice is to plan everything in fine detail before continuing and committing to the execution phase. A well-executed planning phase will result in a higher success rate for the project.

Planning

The planning phase starts with the initial meeting with the client. Here ideas are exchanged and a general sense of scope, time, budget is given from the client. In the case of a client with no prior experience in construction, the project manager will give a rough number based on experience and historical data. An important document that is fabricated during this initial meeting is the "Basis of Design" document. This is a written form of the scope and direction of the project that the client wants to see. It will be used in future steps as a reference point.

Once the project manager understands what the client wants, the next course of action will be to transform the client's idea on to complete construction documents and compute the cost associated with the project. This is an iterative process that is continuously updated through the exchange of information between the client, architect, and contractor (professional cost estimators can be assigned in place of contractor as they serve a similar purpose). The triangular correlation mentioned is illustrated by figure 13.

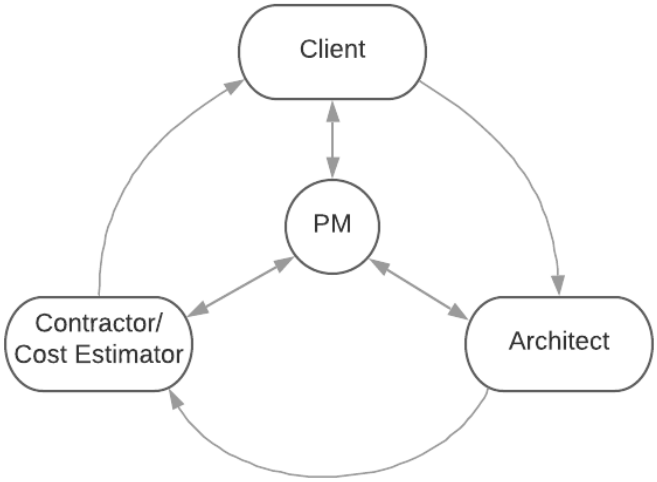

Figure 13: Triangular correlation of client, architect, and contractor/ cost estimator

As seen in the picture, based on the client's idea a concept drawing is made by an architect. Then this drawing is used to retrieve information about costs of project through contact with contractors or with a cost estimator. During the early iterations, it is possible that the cost estimate can be carried out by the project manager through direct contact with contractors. However, in later iterations, as the fine details of the project is brought up by the architect, it is common practice that a professional cost estimator carries out the task of making the cost estimates. The iterations of this process pass through certain design stages that serve as indicators. The design phases are shown in the following figure 14.

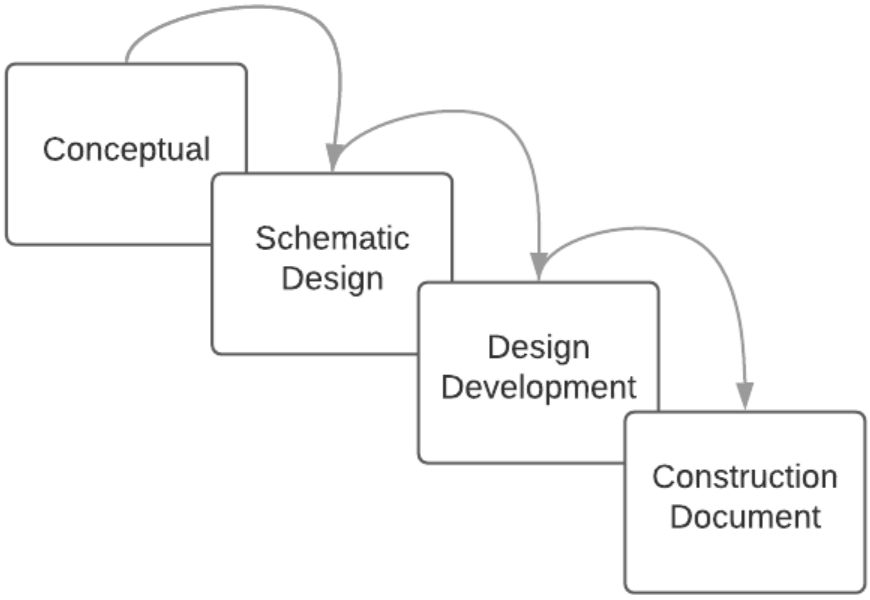

Figure 14: Design stages of planning phase

The conceptual stage shown in this picture is often represented as a part of the schematic design phase. However, it is shown separate here to portray the initial exchange of information between client and project manager before the schematic design process can begin. Each of the phases represent a percent completion of the drawings. The schematic design phase constitutes around 30% completion. Design development carries 60-90% completion. It should be noted that these percentages are averages and depending on the project they can be subject to change. Lastly the construction document is the final document that conveys all the information about the project.

With the completion of the construction document the final activities of the planning phase can take course. These include the steps of finalizing the budget, scope, and time with the client, choosing contractors for the project execution phase, and acquiring any legal documentation that

is necessary such as Site Plan approval. Although these processes are presented in a straight forward means, the actual duration can span months. Especially for the Site Plan approval, which can take up to months.

Execution, Monitoring, and Closure

Once the planning phase is completed the execution of the project begins. During this period a project manager is tasked with keeping track of schedule, cost, and scope of the project. Documentations of the progress will be kept for reports to the clients and added to the database for use as reference in future projects. While the planning phase is completed to the full extent with resource analysis and risk prevention through contingency plans, the project is still susceptible to unforeseen conditions. When such events arise, it is the project managers obligation to solve problematic situations by using the set contingency plan or in a worse case altering the scope, schedule, or budget.

An important aspect of project management, in not only the execution phase but the project as a whole, is that of communication. There are multiple parties working on a given project at any given time. So, it is the responsibility of the project manager to convey information from one party to another with the least amount of data loss in between.

Cost Estimation

The cost estimation process is a sub-process of the planning phase in project management that follows a same procedure illustrated in figure 14 from previous section. Like mentioned before, in conceptualization phase the cost estimator will use quick methods such as expert opinion or project comparison estimating to provide initial cost estimates. As the planning phase progresses and the architect and client brings more information to light, the cost estimator will evaluate their choices and give further estimates. In the schematic design phase material selection and basic floor plans will be presented. During this phase the cost estimator will provide the client with information on “if they can afford the material and finishing choices they’ve selected or not”. During the next phase of design development is when the cost estimator starts his detailed estimate. By analyzing historical data and latest information from contractors, the cost estimator will try to achieve close to real life results. A supporting system known as CSI is used for this calculation. This is a standardized model of all the components in construction project cost estimation that professionals use as a guide for their cost estimates. The final product the cost estimator produces is the construction document.

Results and Discussion

The aim of this research was to optimize the cost estimation process to reduce risk. Consequently, three areas of interest have been investigated for the result. These three topics serve to narrow down the objective to a manageable size and result. A brief overview is given first, continued by detailed explanations.

- Correlation between risk and cost estimation.
- What are problems associated with performing accurate cost estimates.
- Recommendations on optimization of cost.

Risk & Cost Estimation

As mentioned in the literature review section, risk is inherent in any project. It exists in the form of known and unknown risk. While naturally projects have contingency plans for risks with high probability levels, in practice, it is almost impossible to completely eradicate risk in projects due to finite resources and limiting factors of scope, schedule, and cost. The next best alternative is to create contingency plans to a reasonable extent and to perform correct calculations during the planning phase. The term “reasonable extent” is used in this context because the contingency plan is subjective to the client and the unique aspect of individual projects. Thus, it is impossible to say that there exists a precise value for contingency. On the other hand, activities within the planning phase such as scheduling and cost estimation must portray precise values. This is where the correlation between risk and cost estimation is presented. By correctly calculating the cost estimation during the planning stages, it is possible to avoid setbacks during the execution phase. Thus, it is concluded that there is a direct correlation between cost estimation and risk. A well-documented and correctly analyzed cost estimation will reduce potential risks in further project lifecycle.

Difficulties of Cost Estimation

The significance of cost estimation in reduction of risk is apparent. Therefore, to improve this process, first problems associated with conducting a precise cost estimate must be identified. This was achieved by conducting a survey with the project managers at the Square One consulting firm and live interviews with their chief cost estimator.

The survey was sent out to the faculty of Square One who are all project managers. From 25 potential participants 9 completed the survey. There were eight project managers and one construction manager. Primary educational background was Master of Architecture with 6. The average experience of the group was 13 years with the highest being 36.

For the closed questions of the survey, it was explained that there were common difficulties in making accurate cost estimates. The participants were given the ability to rate each statement, from the common difficulties, on their likelihood of effecting the cost estimation in a negative manner. The statements were chosen by analyzing the literature review and consulting with my supervisor. While the full survey is available in the appendix section, the statements with the highest vote rates can be seen in the following figures.

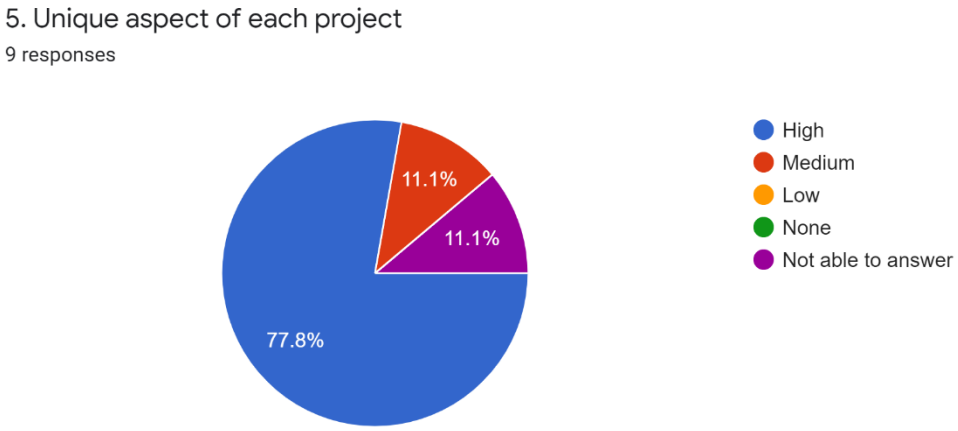

Figure 15: Survey answer on difficulties of cost estimation

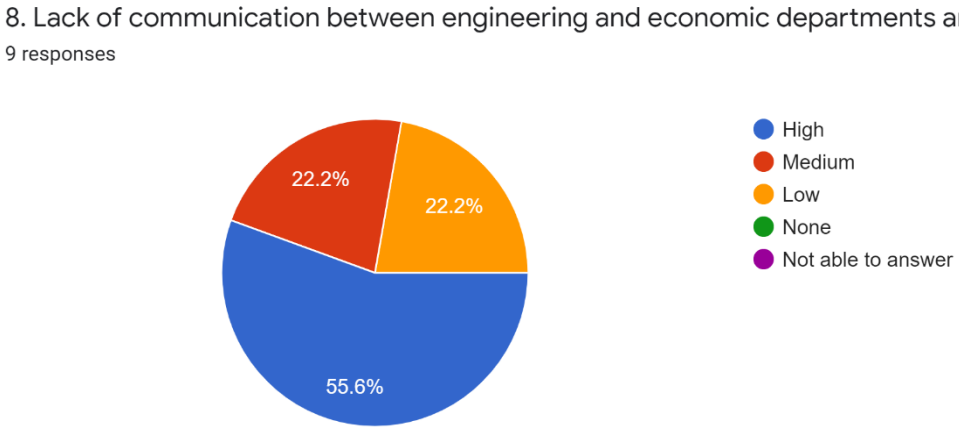

Figure 16: Survey answer on difficulties of cost estimation 2

The information from the survey was then expanded upon by the interviews with the chief cost estimator at Square One. On top of the mentioned issues, the process of always staying up to date and not relying on historical information too much was emphasized. Construction industry is a dynamic environment that changes and shifts constantly, being able to constantly update information and staying relative was the toughest issue when it comes to cost estimation.

Recommendations

A project is a team effort. Thus, it is important to know how to utilize available talent as a project manager. However, knowing who to assign to what task is not enough alone. Information loss is a large issue that needs to be addressed to improve efficiency of project process. A possible method to approach this is by implementing a systemized information exchange process in the company. Also, investing in the database create easy to access information. While historical information can have its pitfalls, it is effective in creating quick estimates. Thus, a larger database is, the greater chance of having information on the unique aspects of different projects. Lastly, even with the rapid advancements in technology, the most reliable source of information remains to be the expertise of individuals who’ve gathered their knowledge over years of experience in the industry. They are a critical component in improving the cost estimation practice in any firm. To utilize this training programs of where newer members can learn from the experts is advised.

Conclusion

With the continues growth of the economy year after year, competition among businesses are growing ever fierce. To survive and possibly even thrive in this environment, companies must focus on expanding their business. Since its formal introduction in the 1960s project-based growth for companies have become very popular. Today it is virtually used in every business sector to promote growth of business. One area where this method has become a standard is that of the construction industry. Unfortunately, the method still faces problems. The primary factor of these problems being the constantly changing dynamic environment of the industry and the risks associated with it. While there are possible methods to mitigate risk, primarily being contingency planning through risk management, it is impossible to eliminate this factor all together.

In project management, risk is most harmful in the latter parts of the project lifecycle. However, through proper planning and implementation of a project the probability of risk can be reduced. In the planning phase one important area of attention is that of cost estimation. A poorly made cost estimation can result in project failure while a precisely conducted estimate can ensure a successful project. Thus, it has become the interest of project managers to improve this process to reduce the possibility of risk.

With this thesis, an analysis on the current state of cost estimation was performed. This was achieved by combining theoretical research with that of practical analysis of a case study. A construction project management consulting company collaborated on to provide practical expertise and information on the process of cost estimation and project management. Through surveys and interviews with the management firm and study of existing literature the following results were obtained. Investigation of areas of difficulties in cost management revealed that the factors which influenced the cost estimation process were:

- Unique aspect of Projects
- Communicational difficulties between departments
- Ever changing state of costs in the industry

As a result, a possible method of creating better communication systems within the organization, better managed database for historical information, and transfer of expertise from experienced personnel to newer members was recommended.

References

1. Perry JG, Hayes RW. RISK AND ITS MANAGEMENT IN CONSTRUCTION PROJECTS. Proc Inst Civ Eng. 1985;
2. Barlett C. Project Risk Analysis and management (PRAM) Guide. 2004.
3. Gray CF, Larson EW. Project Management: The Managerial Process: Fifth edition. McGraw-Hill. 2011.
4. Ward S, Chapman C. Transforming project risk management into project uncertainty management. Int J Proj Manag. 2003;
5. Boehm B, Abts C, Chulani S. Software development cost estimation approaches - A survey. Ann Softw Eng. 2000;
6. Dysert L. Is estimate accuracy an oxymoron? Cost Eng (Morgantown, West Virginia). 2007;
7. Yoe C. Risk Analysis Framework for Cost Estimation in association with: Planning and Management Consultants. 2000;
8. Andrew BM& BR. Project Management for Scientists and Engineers. Connexions, Rice University, Houston, Texas; 2009.
9. Weaver P. Trends in Modern Project Management, Past, Present & Future. 2007;
10. Shenhar, A. J, Levy, O., and Dvir D. Mapping the dimensions of project success. Proj Manag Journal, 1997, 28 5—13. 1997;Internatio.
11. McCracken J. Oxford dictionary of English. In 2003.
12. Archibald, R.D. and Prado D. Introduction to Maturity in Project Management. PM World J. 2014;
13. Institution BS. No TitleProject Management- Part3: Guide to the management of business related project risk. London; 2000.
14. Morris PWG. Developing Project Management. In: Reconstructing Project Management. 2013.
15. Project Management Institute. A guide to the project management body of knowledge (PMBOK® guide). Project Management Journal. 2008.
16. Wheatley M. The Importance of Project Management: New research into the role of project management in a modern developed economy. 2012;
17. Jones CP. Investments: Analysis and Management. 10th ed. John Wiley & Sons. 2007.
18. Hillson D. Extending the risk process to manage opportunities. Int J Proj Manag. 2002;
19. Raftery J. Risk Analysis in Project Management. 1st Ed. 1994.
20. Gabel M. Project risk management guidance for WSDOT projects. … State Department of

Transportation–Administrative and …. 2010.

21. Cooper, D. F., Grey, S., Raymond, G., & Walker P. Project risk management guidelines: Managing risk in large projects and complex procurements. 2005.
22. Finnerty J. Project Financing: Asset-Based Financial Engineering. John Wiley Sons. :384 p.
23. Chang K. Product Manufacturing and Cost Estimating Using CAD/CAE. Elsevier Inc. 2013;237–94.
24. Tanaka, M., Yoshikawa, T., Innes, J., Mitchell F. Contemporary Cost Man-agement. Chapman Hall. 1993;185.
25. Kerzner H. Patent Project Management: A SYSTEMS APPROACH TO PL ANNING, SCHEDULING, AND CONTROLLING. Patent Project Management. 2010.
26. Taylor J. Project Scheduling and Cost Control: Planning, Monitoring and Controlling the Baseline. J Ross Publ. 2007;313.
27. Artto K., Martinsuo M. KJ. Project business – the project manage-ment textbook. 2011.
28. Gonçalves, T., Gaio, C., Silva M. Target costing and innovation-explora-tory configurations: A comparison of fsQCA, multivariate regression, and variable clus-ter analysis. J Bus Res. 2018;89:378–84.
29. Stewart, R., Wyskida RM. Cost Estimator's Reference Manual. John Wiley Sons. 1987;620.
30. Dagostino, F.R., Peterson SJ. Estimating in Building Construction. Pear-son Educ Inc. 2011;273.
31. Aqil BSM. Inductive & Deductive Research Approach. 2008.
32. Naoum.S. Dissertation Research and Writing for Construction Students, 2nd Ed. Butterworth-Heinemann; 2007.
33. Greener S. Business Research Methods.[e-book] Dr. Sue Greener and Ventus Publishing ApS. Available through:< http://www. bookbon. com> 2008.

Appendix

Closed Questions used for survey:

There are common factors which contribute to the difficulties of conducting cost estimations. In the following questions common factors are presented. Please choose how much each factor influences the difficulties of cost estimation.

- 1. Size of the project (large projects are more difficult)
- 2. Human error (mistakes of under or over estimating)
- 3. Inaccuracy of price given by contractors
- 4. Lack of historical information
- 5. Unique aspect of each project
- 6. Novelty of undertaken solution and implemented technology
- 7. Not clear which item to allocate cost to
- 8. Lack of communication between engineering and economic departments and or staff
- 9. High resource consumption of detailed estimates