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Financial Modeling of Operational Costs for the Implementation of ESG Frameworks such as Towards Sustainable Mining (TSM): A Case Study of a Mongolian Mining Company

Bachelor Thesis

by

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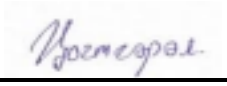
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Abstract

This study aims to develop a financial model to estimate the operational costs associated with implementing Environmental, Social, and Governance (ESG) frameworks, specifically the Towards Sustainable Mining (TSM) standard, in the mining sector.

The research adopts a case study approach combined with financial modeling, using Erdenet Mining Corporation in Mongolia as a representative example. The study systematically identifies and classifies TSM-related costs by linking the nine TSM protocols with operational activities and key cost drivers. Costs are categorized into capital expenditure (CAPEX), operating expenditure (OPEX), compliance, consulting, and administrative costs.

An Excel-based financial model is developed to estimate cost flows over the period 2026–2030, incorporating scenario and sensitivity analysis. The results indicate that TSM implementation requires significant initial investment, with capital expenditure dominating in the early stage, while recurring operational and compliance costs become more prominent over time. The total estimated cost over five years is approximately 30.2 billion MNT, with a Net Present Value (NPV) of 24.3 billion MNT, suggesting that TSM implementation is financially viable in the long term.

The findings also reveal that major cost drivers include human resources, monitoring systems, technical infrastructure, compliance requirements, and consulting services. Environmental (E) costs constitute the largest share of total expenditures, particularly in areas such as water management, tailings management, and climate-related activities.

In conclusion, while the implementation of TSM increases short-term operational costs, it provides long-term financial and strategic benefits by reducing risks, improving operational stability, and enhancing investor confidence. Therefore, ESG and TSM implementation should be considered a strategic investment rather than a cost burden in the mining industry.

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CHAPTER 1. INTRODUCTION

1.1 Background of the study

The mining sector plays a crucial role in the economic development of Mongolia, contributing significantly to gross domestic product (GDP), export revenues, government budget income, and job creation [1,2]. Major mining projects such as copper, gold, and coal have become key drivers of economic growth and have strengthened integration with global commodity markets [2]. In addition, the mining sector has increased Mongolia's economic dependence on global resource demand, making sustainability issues more important.

As global demand for mineral resources continues to rise, mining companies are increasingly expected not only to operate efficiently but also to ensure responsible and sustainable operations [3,4]. This shift reflects growing international pressure on companies to balance economic performance with environmental and social responsibility.

In recent years, international requirements related to environmental protection, social responsibility, and corporate governance have significantly increased. These requirements are commonly expressed through the Environmental, Social, and Governance (ESG) framework, which has become a key benchmark for evaluating organizational sustainability and responsible business practices [4]. Investors, governments, and international organizations are increasingly requiring companies to ensure transparency, accountability, and long-term sustainability.

One of the most widely used frameworks for promoting sustainability in mining is the Towards Sustainable Mining (TSM) initiative, developed by the Mining Association of Canada [5]. TSM provides structured protocols and performance indicators that allow mining companies to measure, evaluate, and improve their environmental and social performance. The framework includes key areas such as stakeholder engagement, environmental management, tailings management, water stewardship, biodiversity conservation, occupational health and safety, and crisis management.

Implementation of the TSM framework requires mining companies to establish internal governance systems, improve operational processes, and allocate sufficient financial resources. It also requires investment in monitoring systems, environmental infrastructure, training programs, reporting systems, and stakeholder communication activities. These requirements create additional operational costs and compliance-related costs, which must be incorporated into financial planning and cost management systems [3].

Despite the growing importance of ESG standards and sustainability practices, there is still a lack of structured financial models in emerging mining economies like Mongolia to accurately estimate the costs associated with implementing frameworks such as TSM [1]. Without systematic cost modeling, companies face difficulties in budgeting, decision-making, and evaluating the financial impact of sustainability initiatives.

Therefore, developing a financial model to identify and estimate TSM-related costs is essential for improving financial planning, increasing investment transparency, and supporting the integration of ESG principles into long-term strategic management.

1.2 Research Problem

The global mining industry is increasingly adopting ESG standards to ensure responsible and sustainable resource utilization [6]. Among these frameworks, the TSM initiative has become an important tool for improving environmental performance, strengthening stakeholder relationships, and enhancing operational transparency [5,7].

However, most existing academic studies focus on environmental performance, social responsibility, and ESG reporting, while relatively limited attention has been given to financial and operational cost structures associated with sustainability implementation [1].

At the mine-site level, there is a lack of a systematic financial model that can identify, classify, and estimate operational costs and compliance costs related to TSM implementation. This gap makes it difficult for companies to evaluate the cost-effectiveness of sustainability initiatives and integrate them into financial decision-making.

1.3 Research Objective

The objective of this study is to develop a structured financial model to estimate the operational costs associated with implementing the TSM framework at the mine-site level.

1.4 Research Tasks

Task 1 – Finance and Cost Management

- Identify TSM-related cost components
- Develop a financial model based on CAPEX and OPEX
- Estimate short-term costs and recurring operational costs

Task 2 – Sustainability and Compliance

- Link TSM protocols with key cost drivers
- Analyze the impact of ESG requirements on cost structures
- Evaluate the cost-benefit relationship of compliance and risk reduction

1.5 Research Questions

1. What types of costs arise at the operational level when implementing TSM standards?
2. How can these costs be systematically classified and incorporated into a financial model?
3. How do TSM implementation costs affect operational expenses and financial planning?
4. How can a financial model support decision-making in sustainable mining?

1.6 Scope and Limitations of the Study

This study focuses on developing a financial model to estimate operational costs associated with implementing the TSM framework at the mine-site level. It analyzes how TSM requirements influence the cost structure of mining operations and how these costs can be identified, classified, and integrated into financial planning.

The study includes both operational expenditures (OPEX) and selected capital expenditures (CAPEX) related to TSM implementation. The cost analysis focuses on areas such as environmental monitoring, infrastructure development, training, and stakeholder engagement.

The TSM framework consists of nine core protocols [5]:

- Indigenous and Community Relationships
- Safety and Health
- Crisis Management and Communication
- Tailings Management
- Water Stewardship
- Biodiversity Conservation
- Energy Use and Emissions Management
- Labor Standards
- Responsible Supply Chain Management

The study uses Erdenet Mining Corporation as a case study to illustrate how TSM requirements generate real operational and compliance costs.

However, several limitations exist. First, detailed financial data related to TSM implementation is often not publicly available; therefore, the study relies on secondary data sources and industry benchmarks. Second, the developed model represents an estimated cost structure, not exact company data. Third, the study mainly focuses on operational and compliance costs, and does not fully include market valuation, investor perception, or long-term profitability impacts.

1.7 Significance of the Study

This study contributes to understanding the financial implications of sustainability frameworks in the mining sector, particularly ESG standards and the TSM initiative.

First, it develops an analytical framework to identify and estimate operational and compliance costs, improving financial transparency and planning.

Second, it contributes to academic research by focusing on financial and cost modeling, which is less explored compared to environmental aspects.

Third, it provides practical value for mining companies, managers, and policymakers by improving decision-making, cost efficiency, and ESG implementation strategies.

Finally, the study supports strategic management by helping organizations balance compliance costs, operational efficiency, and long-term sustainability goals.

CHAPTER 2. LITERATURE REVIEW

2.1 ESG Framework in the Mining Sector

Over the past decades, the concept of Environmental, Social, and Governance (ESG) has evolved into an important framework for evaluating organizational sustainability and responsible business practices across various industries [4]. In the mining sector, ESG is particularly significant due to the nature of mining activities, which have substantial environmental impacts, involve close interaction with local communities, and require complex governance structures. As a result, mining companies are increasingly expected to integrate ESG principles into their operational strategies and decision-making processes.

The environmental dimension of ESG focuses on how mining companies manage their impact on the natural environment. This includes greenhouse gas emissions, water usage, waste management, biodiversity conservation, and land rehabilitation [3]. Since mining activities involve intensive resource extraction and can cause significant environmental changes, effective environmental management systems are essential to minimize negative ecological impacts.

The social dimension of ESG emphasizes the relationships between mining companies and their stakeholders, including local communities, employees, indigenous populations, and government institutions. Within this dimension, mining companies are expected to

ensure safe working conditions, respect human rights, maintain transparent communication with communities, and contribute to regional development [1].

The governance dimension of ESG refers to the structures and processes through which companies are directed and controlled. It includes transparency in reporting, compliance with legal and regulatory requirements, risk management practices, accountability mechanisms, and effective corporate governance systems. In the mining sector, strong governance practices are essential for building investor confidence and ensuring long-term sustainability [6,8].

To support the implementation of ESG principles, several international sustainability frameworks and standards have been developed for the mining industry. These frameworks provide structured approaches for measuring performance, improving operational practices, and reporting sustainability outcomes. Examples include the Towards Sustainable Mining (TSM) initiative developed by the Mining Association of Canada, as well as sustainability frameworks developed by the International Council on Mining and Metals [3].

Among these frameworks, the Towards Sustainable Mining (TSM) initiative is one of the most widely adopted sustainability programs in the mining sector [5]. It provides protocols and performance indicators designed to improve transparency, environmental protection, and stakeholder engagement. Through the implementation of TSM protocols, mining companies are able to systematically monitor, evaluate, and improve their sustainability performance.

The importance of ESG implementation has increased significantly among investors and financial institutions. ESG performance is increasingly used as a key criterion in evaluating mining companies, with those demonstrating strong ESG practices being perceived as having lower long-term risks and greater sustainability potential [6].

In Mongolia and other emerging mining economies, the integration of ESG frameworks into mining operations is becoming increasingly important. International investors, development banks, and regulatory bodies are requiring mining companies to comply with global sustainability standards [2]. As a result, companies must not only implement ESG

principles but also understand and plan for the financial and operational costs associated with these frameworks.

Therefore, studying ESG frameworks in the mining sector is essential for understanding how sustainability standards influence operational management, financial planning, and long-term strategic decision-making.

2.2 Overview of the Towards Sustainable Mining (TSM) Framework

The Towards Sustainable Mining (TSM) initiative is an internationally recognized sustainable mining program developed by the Mining Association of Canada. This framework aims to improve the environmental and social performance of mining operations while promoting transparency and responsible resource development [5,7].

The TSM framework provides a structured management system that enables mining companies to measure, monitor, and improve sustainability performance at the mine-site level. The program is based on the principles of continuous improvement, stakeholder engagement, and transparent reporting of sustainability performance. Companies implementing TSM are required to assess their performance using standardized indicators and publicly disclose their results [5,7].

A key feature of the TSM framework is its set of protocols and performance indicators used to evaluate sustainable mining practices. Each protocol includes criteria and rating levels to assess performance in a specific operational area. These protocols collectively address a wide range of environmental, social, and governance issues in mining operations [7,8].

The TSM framework consists of nine core protocols:

1. Indigenous and Community Relationships

This protocol focuses on establishing transparent and trust-based relationships with local communities, herders, and stakeholders. It includes community engagement, social impact management, grievance mechanisms, and support for local development [8].

Associated costs include stakeholder mapping and analysis, community consultations, establishment of community relations offices, grievance management systems, local

development funds, compensation to herders, land use agreements, communication materials, salaries of community relations staff, and social impact monitoring.

2. Safety and Health

This protocol aims to ensure systematic management of employee safety and health. It includes accident prevention, safety training, health monitoring, and the development of a safety culture [3,8].

Costs include emergency response equipment, communication systems, emergency planning, training programs, and simulation drills.

3. Crisis Management and Communications

This protocol ensures preparedness for emergency situations such as accidents or environmental incidents. It includes risk assessment, emergency planning, and communication strategies [8].

Costs include monitoring systems, inspections, software systems, and emergency preparedness measures.

4. Tailings Management

This protocol focuses on the safe and sustainable management of tailings storage facilities. It includes geotechnical monitoring, dam safety, and risk prevention [7,9].

Costs include monitoring stations, laboratory testing, water treatment facilities, water recycling systems, and hydrological studies.

5. Water Stewardship

This protocol ensures responsible use and protection of water resources. It includes water monitoring, pollution reduction, reuse systems, and protection of local water sources [7].

Costs include environmental impact assessments, baseline studies, biodiversity monitoring, rehabilitation, monitoring equipment, and environmental offset measures.

6. Biodiversity Conservation Management

This protocol focuses on minimizing the impact of mining operations on biodiversity. It includes ecosystem protection, rehabilitation, wildlife protection, and environmental monitoring [7,8].

Costs include training programs, monitoring systems, environmental equipment, and conservation initiatives.

7. Energy Use and Greenhouse Gas Emissions

This protocol focuses on improving energy efficiency and reducing greenhouse gas emissions. It includes energy monitoring, fuel efficiency, renewable energy use, and carbon management [2,7].

Costs include energy monitoring systems, fuel tracking systems, renewable energy installations, efficiency improvements, emission monitoring, and carbon accounting services.

8. Preventing Child and Forced Labor

This protocol ensures that child labor and forced labor are prohibited throughout the supply chain. It includes human rights policies, supplier monitoring, and labor standards compliance [6,8].

Costs include supplier audits, human rights assessments, monitoring systems, training programs, and supplier codes of conduct.

9. Climate Change

This protocol focuses on climate change adaptation and mitigation. It includes carbon strategies, climate risk assessment, and long-term emission reduction planning [4,7].

Costs include stakeholder consultations, advisory services, climate risk assessments, and long-term mitigation planning.

Each protocol includes performance indicators and rating levels, typically ranging from A to AAA, where AAA represents the highest level of sustainability performance [5,7].

An important characteristic of the TSM framework is the requirement for external verification and public reporting. Participating companies must conduct self-assessments

and undergo third-party verification, which enhances transparency and strengthens stakeholder trust [5,8].

Implementing the TSM framework requires significant financial and organizational resources. Companies must invest in monitoring systems, environmental infrastructure, training programs, stakeholder engagement activities, and reporting systems. As a result, TSM implementation generates both operational and compliance-related costs [3,7].

Therefore, understanding the structure and requirements of the TSM framework is essential for analyzing the financial and operational impacts of sustainability implementation in mining companies.

TSM 9 Protocols → Cost Mapping Table

TSM протокол ба зардлын үялдаа			
TSM протокол	**Үндсэн зардлын ангилал**	**Жишээ зардлын зүйлс**	**Зардлын гол хөдөлгөгч хүчин зүйл**
Орон нутгийн хамтын ажиллагаа	Үйл ажиллагааны зардал	Олон нийтийн баг, уулзалт, орон нутгийн хөтөлбөр	Оролцогч талуудын оролцооны эрчим
Аюулгүй байдал ба эрүүл мэнд	Үйл ажиллагааны зардал	Сургалт, ХАБ-ын хэрэгсэл, хүний нөөц	Ажиллах хүчний хэмжээ ба сургалтын давтамж
Хямралын менежмент	Захиргааны зардал	Сургуулилалт, мэдээллийн төлөвлөгөө	Жилийн сургуулилалтын тоо
Хаягдлын сангийн менежмент	CAPEX / OPEX	Instrumentation, inspections, reviews	Facility criticality & inspection regime
Усны менежмент	CAPEX / OPEX	Sampling equipment, testing, treatment monitoring	Sampling frequency & water risk
Биологийн олон янз байдлын хамгаалал	Зөвлөх үйлчилгээ	Ecological studies, habitat reviews	Site sensitivity & study scope
Уур амьсгалын өөрчлөлтийн менежмент	Хөрөнгө оруулалтын зардал	Energy/GHG monitoring systems	Metering depth & reporting maturity
Preventing Child & Forced Labour	Нийцлийн зардал	Supplier due diligence, audits	Supplier base & audit cadence
Хариуцлагатай ханган нийлүүлэлт	Захиргааны зардал	Supplier screening, records, follow-up	Procurement complexity
Хүүхдийн болон албадан хөдөлмөрөөс сэргийлэх	Нийцэл / захиргаа	Supplier due diligence, human rights assessment, code of conduct	Supplier base & monitoring maturity
Уугуул иргэд ба FPIC	Орон нутгийн зардал / нийцэл	FPIC, cultural heritage, indigenous advisory	Consultation depth & agreement scope

The table illustrates the relationship between the Towards Sustainable Mining (TSM) protocols and their associated cost structures within mining operations. Each protocol is linked to specific cost categories, including operational, administrative, capital (CAPEX), and social expenditures, reflecting the broader economic and sustainability context of the mining sector [1,2].

The cost drivers identified in the table demonstrate that expenditures vary depending on the functional scope of each protocol. Social performance protocols, such as Indigenous and community relationships, are primarily influenced by stakeholder engagement and

consultation intensity, which align with international sustainable development and responsible business conduct principles [4,6]. Occupational health and safety costs are driven by workforce size, training requirements, and compliance with established safety standards within mining operations [3].

Environmental protocols, including tailings and water management, require both capital investments and ongoing operational monitoring. These costs are largely influenced by site-specific risks, regulatory requirements, and global standards such as the Global Industry Standard on Tailings Management [9]. Similarly, biodiversity conservation and environmental protection measures reflect broader sustainability commitments outlined in international mining frameworks [3,8].

Governance-related protocols, including responsible supply chain management and the prevention of child and forced labor, involve administrative and compliance-related costs. These are influenced by supplier complexity, audit frequency, and due diligence processes, in line with OECD and international best practices [6,8]. In addition, climate-related initiatives, such as energy use and greenhouse gas (GHG) emissions management, require investments in monitoring systems and reporting mechanisms, reflecting increasing global emphasis on environmental accountability [3,4].

Overall, the integration of TSM protocols into cost structures demonstrates that sustainability performance is closely linked to financial planning and resource allocation. The TSM framework provides a structured approach to aligning environmental, social, and governance (ESG) requirements with operational and financial decision-making in the mining sector [5,7].

2.3 Cost Classification in Mining

Cost classification in mining refers to the systematic categorization of costs associated with mining operations based on their nature, function, and time horizon. This classification typically includes capital expenditure (CAPEX), operating expenditure (OPEX), compliance costs, consulting costs, and administrative costs. Such a structured approach enables mining companies to better understand cost drivers, improve financial planning, and enhance decision-making across the project life cycle [1,3].

In mining operations, cost classification is essential due to the complexity and capital-intensive nature of the industry. Different cost categories reflect various stages of mining activities, including development, production, environmental management, and closure. For example, CAPEX is associated with long-term investments in infrastructure and equipment, while OPEX represents the recurring costs required to sustain daily operations. In addition, compliance, consulting, and administrative costs capture regulatory, governance, and management-related expenditures, which have become increasingly important with the adoption of sustainability frameworks such as TSM and ESG standards [5,6,7].

A comprehensive cost classification system allows mining companies to align financial resources with operational and sustainability objectives. It also supports transparency, cost control, and risk management by clearly identifying where and how financial resources are allocated across environmental, social, and governance (ESG) activities [3,8].

Definition of CAPEX (Capital Expenditure)

Capital expenditure (CAPEX) refers to the funds invested by a company to acquire, construct, upgrade, or extend long-term physical assets such as infrastructure, equipment, and facilities. These expenditures are typically made to improve operational capacity, enhance efficiency, or meet regulatory and sustainability requirements, and they provide economic benefits over multiple years [3,8].

In the mining industry, CAPEX plays a critical role due to the capital-intensive nature of operations. It includes investments in mine development, processing plants, tailings storage facilities, water treatment systems, and environmental monitoring infrastructure. Such investments are essential for establishing the technical and environmental foundations required for mining activities and for complying with international standards and sustainability frameworks such as the TSM initiative [5,7].

Unlike operating expenditure (OPEX), which covers recurring day-to-day costs, CAPEX represents long-term financial commitments that are typically capitalized and depreciated

over the life of the asset. Effective management of CAPEX is crucial for ensuring project feasibility, long-term sustainability, and risk reduction in mining operations [3].

Definition of OPEX (Operating Expenditure)

Operating expenditure (OPEX) refers to the ongoing, day-to-day costs incurred by a company to maintain and support its operational activities. These expenditures are necessary to ensure the continuous functioning of production processes, equipment, and organizational operations, and are typically recognized within a single accounting period [1,3].

In the mining industry, OPEX includes a wide range of recurring costs such as labor, energy consumption, fuel, equipment maintenance, consumables, and transportation. It also covers expenses related to environmental monitoring, safety management, and regulatory compliance, which are essential for maintaining operational efficiency and meeting industry standards [3,6].

Unlike capital expenditure (CAPEX), which involves long-term investments in assets, OPEX represents short-term expenditures that are directly linked to production levels and operational intensity. Effective management of OPEX is critical for cost control, profitability, and ensuring the sustainable operation of mining projects over time [1,3].

Definition of Compliance Costs

Compliance costs refer to the expenditures incurred by a company to meet legal, regulatory, and industry-specific requirements governing its operations. These costs include activities related to environmental monitoring, reporting, permitting, auditing, and adherence to national and international standards. Compliance costs are essential for ensuring that mining operations align with regulatory frameworks and sustainability guidelines, thereby reducing legal risks and enhancing corporate accountability [3,6].

In the mining sector, compliance costs are particularly significant due to strict environmental, health, and safety regulations. Companies must allocate financial resources to maintain compliance with frameworks such as environmental protection laws, occupational safety standards, and international initiatives like the TSM framework.

Although these costs may increase short-term expenditures, they contribute to long-term risk mitigation and improved stakeholder trust [5,7].

Definition of Consulting Costs

Consulting costs refer to expenditures associated with hiring external experts or professional service providers to support specialized activities within a company. These services may include environmental and social impact assessments, feasibility studies, sustainability reporting, risk analysis, and strategic advisory functions.

In mining operations, consulting costs are often project-based and arise when internal expertise is insufficient to address complex technical, environmental, or regulatory challenges. External consultants play a key role in supporting compliance, improving operational efficiency, and ensuring alignment with international best practices and sustainability standards [3,8]. As mining projects increasingly adopt ESG principles, consulting costs have become an important component of overall cost structures.

Definition of Administrative Costs

Administrative costs refer to internal expenses related to the management, coordination, and support functions of an organization. These costs include salaries of administrative staff, office operations, documentation, communication systems, and general management activities required to ensure organizational effectiveness.

In the mining industry, administrative costs support governance, reporting, and coordination across different operational units. They are particularly relevant in the implementation of sustainability frameworks, where effective documentation, stakeholder communication, and internal control systems are required. Administrative costs, although indirect, play a critical role in maintaining organizational structure, ensuring compliance, and supporting decision-making processes [6,7].

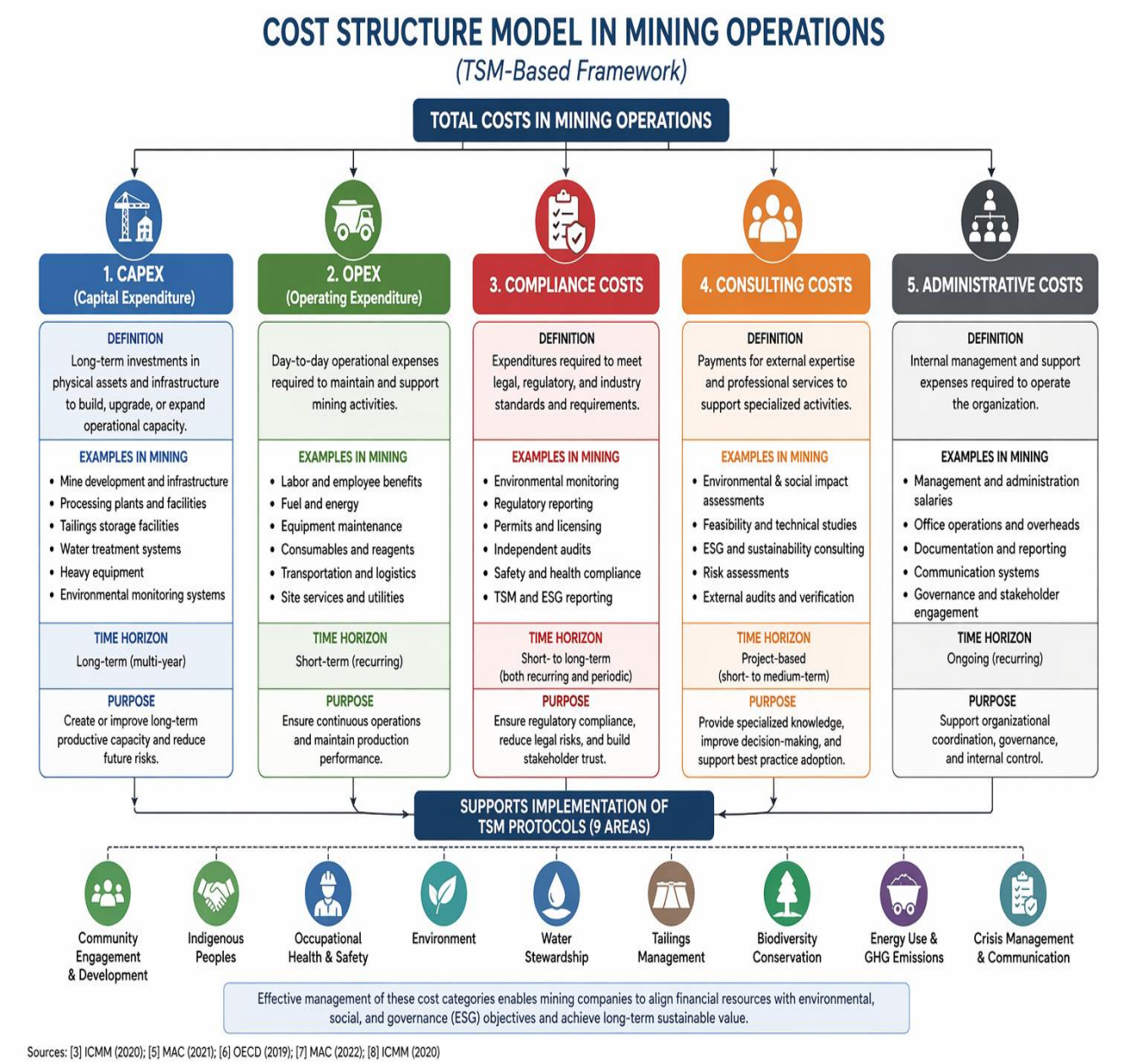


Figure X. Cost Structure Model in Mining Operations (TSM-based Framework)

This figure presents a conceptual model of cost classification in mining operations, structured into five major categories: capital expenditure (CAPEX), operating expenditure (OPEX), compliance costs, consulting costs, and administrative costs. Each category represents a distinct type of financial resource allocation within mining activities.

CAPEX reflects long-term investments in infrastructure and systems, while OPEX includes recurring costs necessary for daily operations. Compliance costs are associated

with meeting regulatory and industry requirements, whereas consulting costs represent expenditures for external expertise and specialized services. Administrative costs support internal management, coordination, and governance functions.

The model also demonstrates how this cost categories collectively support the implementation of the nine Towards Sustainable Mining (TSM) protocols, linking financial structures with environmental, social, and governance (ESG) performance. This integrated approach enhances transparency, supports effective cost management, and aligns operational practices with international sustainability standards [3,6,7].

2.4 TSM Implementation Costs: Global Practices

The implementation of the Towards Sustainable Mining (TSM) framework requires mining companies to allocate financial resources across environmental, social, and governance (ESG) activities. Globally, companies increasingly integrate TSM protocols into financial planning, recognizing their role in risk management and long-term value creation [3,5,7].

TSM implementation costs are generally categorized into capital expenditure (CAPEX), operating expenditure (OPEX), compliance, consulting, and administrative costs. CAPEX includes long-term investments in infrastructure such as tailings facilities, water treatment systems, and monitoring technologies, while OPEX covers recurring operational costs including labor, energy, maintenance, and environmental monitoring [3,9].

Compliance costs arise from regulatory requirements and TSM-related reporting and audits, whereas consulting costs involve external expertise for environmental assessments, ESG reporting, and risk analysis. Administrative costs support internal management, coordination, and governance processes [6,8].

Global practices show that mining companies increasingly integrate sustainability-related costs into overall financial planning rather than treating them as separate expenditures. Investments in advanced technologies and environmental systems help reduce long-term operational and compliance costs, particularly in areas such as tailings and water management [3,9].

In addition, stakeholder engagement and social performance are critical cost components, as they support the social license to operate and reduce the risk of project delays and conflicts [4,6].

Overall, TSM implementation costs are not only operational expenses but also strategic investments that enhance sustainability performance, reduce risks, and align mining operations with international standards [5,7].

2.5 TSM, Risk Reduction & Financial Performance

In the mining industry, sustainability frameworks are increasingly linked to risk management and long-term financial performance. Implementing structured sustainability programs helps mining companies reduce operational risks, improve environmental management, and strengthen relationships with stakeholders. The Towards Sustainable Mining (TSM) initiative provides a systematic approach for identifying and managing environmental, social, and governance (ESG) risks in mining operations [5,7].

Mining activities involve various types of risks, including environmental incidents, operational failures, regulatory non-compliance, and social conflicts with local communities. These risks can lead to production interruptions, legal liabilities, reputational damage, and significant financial losses. Sustainability frameworks aim to reduce these risks by promoting responsible operational practices, transparent reporting, and continuous performance improvement [3].

One of the key mechanisms through which TSM contributes to risk reduction is improved environmental and operational monitoring. For example, protocols related to tailings management, water stewardship, and biodiversity conservation require mining companies to implement monitoring systems and risk management procedures. These measures help detect potential environmental problems at an early stage and reduce the likelihood of major environmental accidents [9].

Another important aspect of risk reduction is stakeholder engagement. Mining companies must maintain positive relationships with local communities, governments, and other stakeholders. The TSM protocol on Indigenous and community relationships emphasizes communication, consultation, and conflict resolution mechanisms. Effective stakeholder

engagement reduces the risk of social conflicts, project delays, and operational disruptions [4,6].

In addition to risk reduction, sustainability practices can also influence the financial performance of mining companies. Many international investors and financial institutions consider ESG performance when making investment decisions. Companies with strong sustainability practices are often perceived as having lower long-term risks and better governance structures [8].

Furthermore, improved environmental management and operational efficiency may lead to cost savings in the long term. For example, energy efficiency improvements, water recycling systems, and better waste management practices can reduce operational costs while improving environmental performance. Although sustainability initiatives may require additional upfront investment, they contribute to long-term operational stability and financial resilience.

Therefore, integrating TSM into mining operations provides both risk management benefits and long-term financial advantages. Understanding this relationship is essential for developing financial models that evaluate the economic implications of TSM implementation [5].

2.6 Research Gap

Despite the growing importance of sustainability frameworks and ESG practices in the mining industry, several research gaps remain in the existing literature. Many studies focus on environmental and social impacts or corporate sustainability reporting, while fewer studies analyze the financial implications of sustainability frameworks at the operational level [3].

Existing research emphasizes environmental protection, corporate social responsibility, and stakeholder engagement. However, these studies rarely examine the detailed cost structures associated with implementing sustainability frameworks such as TSM [5,7].

In particular, there is limited research that systematically identifies and categorizes operational costs related to sustainability implementation. Mining companies must invest in environmental monitoring systems, safety improvements, community engagement

programs, compliance activities, and reporting mechanisms. However, the financial modeling of these sustainability-related expenditures remains underdeveloped in both academic literature and industry practice.

This research gap is especially evident in emerging mining economies such as Mongolia, where the adoption of international sustainability frameworks is increasing. Although mining companies are gradually integrating ESG practices, there is limited research examining the cost implications of sustainability implementation within the local context [1,2].

Furthermore, many mining companies lack structured financial models that clearly estimate operational and compliance costs associated with implementing frameworks such as TSM. Without a systematic cost modeling approach, companies may face challenges in budgeting, financial planning, and evaluating the economic feasibility of sustainability initiatives.

Therefore, this study addresses this gap by developing a structured financial cost model that identifies and estimates the operational costs associated with TSM implementation at the mine-site level. By linking TSM protocols with cost drivers, the research provides a practical framework to support financial planning, sustainability management, and decision-making [7].

This study is based on quantitative analysis methods, and the processes of data processing, modeling, and result computation were carried out using Microsoft Excel. Within the scope of the research, cost modeling, scenario analysis, and sensitivity analysis techniques were applied.

CHAPTER 3. METHODOLOGY AND COST MODEL DESIGN

Global Sustainability Requirements

↓

ESG Framework

↓

Towards Sustainable Mining (TSM) Protocols

↓

Operational Sustainability Activities

↓

Cost Drivers

↓

Financial Model Variables

↓

Estimated TSM Implementation Cost

↓

Operational and Strategic Decision Making

3.1 Research Design

This study adopts a case study research design combined with a financial modeling approach to examine the operational costs associated with implementing sustainability frameworks in the mining industry. Case study research is widely used to explore complex real-world phenomena in depth, particularly in sustainability and organizational research [10].

The study focuses on the Towards Sustainable Mining (TSM) framework, which is used as the analytical framework for identifying sustainability-related operational activities and cost drivers within mining operations. The TSM framework provides a structured set of protocols and performance indicators that guide responsible mining practices across environmental, social, and governance dimensions [5,7].

In this research, the framework is used to identify the key operational activities and management requirements that may generate additional financial costs when sustainability standards are implemented at the mine-site level. By using the TSM

protocols as a reference framework, the study is able to systematically analyze how sustainability requirements translate into operational expenditures [14].

To analyze these cost implications in a practical context, the study applies a case study approach. The case study method is widely used in sustainability and mining research because it allows an in-depth examination of organizational practices, operational processes, and cost structures within a specific mining operation [11].

In this study, the case analysis focuses on Erdenet Mining Corporation, one of the largest mining enterprises in Mongolia. The company was selected as a representative case due to its large-scale mining operations, its importance to the national mining sector, and the increasing emphasis on environmental management and sustainability practices within its operations [1,2].

Based on the case study analysis, the research develops a structured financial cost model designed to estimate the operational and compliance costs associated with TSM implementation. The model identifies key cost drivers related to sustainability activities and categorizes them into major financial components, including capital expenditure (CAPEX), operational expenditure (OPEX), compliance costs, consulting services, and administrative costs [13].

The purpose of this research design is to create a systematic analytical framework that connects sustainability requirements with financial planning and cost management in mining operations. By integrating the TSM sustainability framework, a case study approach, and a financial cost modeling methodology, the research provides insights into how mining companies can better estimate and manage the financial implications of sustainability implementation [3,6,8].

3.2 Data Collection

This study uses multiple data sources to support the development of the financial cost model for the implementation of the TSM framework. The use of different data sources improves the reliability and validity of the research findings and allows a more comprehensive understanding of sustainability-related cost structures in mining operations [12].

The research primarily relies on secondary data sources, including company reports, sustainability reports, industry publications, and academic literature related to ESG and sustainable mining practices. These sources provide important information on sustainability management practices, operational activities, and environmental performance indicators in the mining industry [15].

One of the main data sources used in this study is the publicly available documentation of Erdenet Mining Corporation in Mongolia. Company reports and publicly available sustainability-related information are analyzed in order to understand the operational structure, environmental management practices, and potential sustainability-related cost drivers within the organization [1,2].

In addition to company-level information, the study also utilizes industry guidelines and sustainability frameworks that provide structured information on responsible mining practices. These include sustainability standards, ESG guidelines, and technical documentation related to the TSM framework developed by the Mining Association of Canada [5,7].

The research also incorporates secondary academic literature on sustainable mining, ESG implementation, and financial cost modeling. Academic studies, industry reports, and sustainability research provide theoretical insights into cost structures, sustainability investments, and operational management practices in the mining sector [16].

In addition, expert assumptions and industry benchmarks are used to estimate certain cost components where detailed company-level financial data may not be publicly available. These assumptions are based on information from industry reports, sustainability studies, and commonly observed practices in large-scale mining operations [3,6,9].

This study is based on quantitative analysis methods and was carried out using Microsoft Excel for data processing, modeling, and result calculation. The research employed cost modeling, as well as scenario and sensitivity analysis techniques.

3.3 Structure of the Financial Model

In this study, an Excel-based financial model was developed to estimate the costs associated with the implementation of TSM.

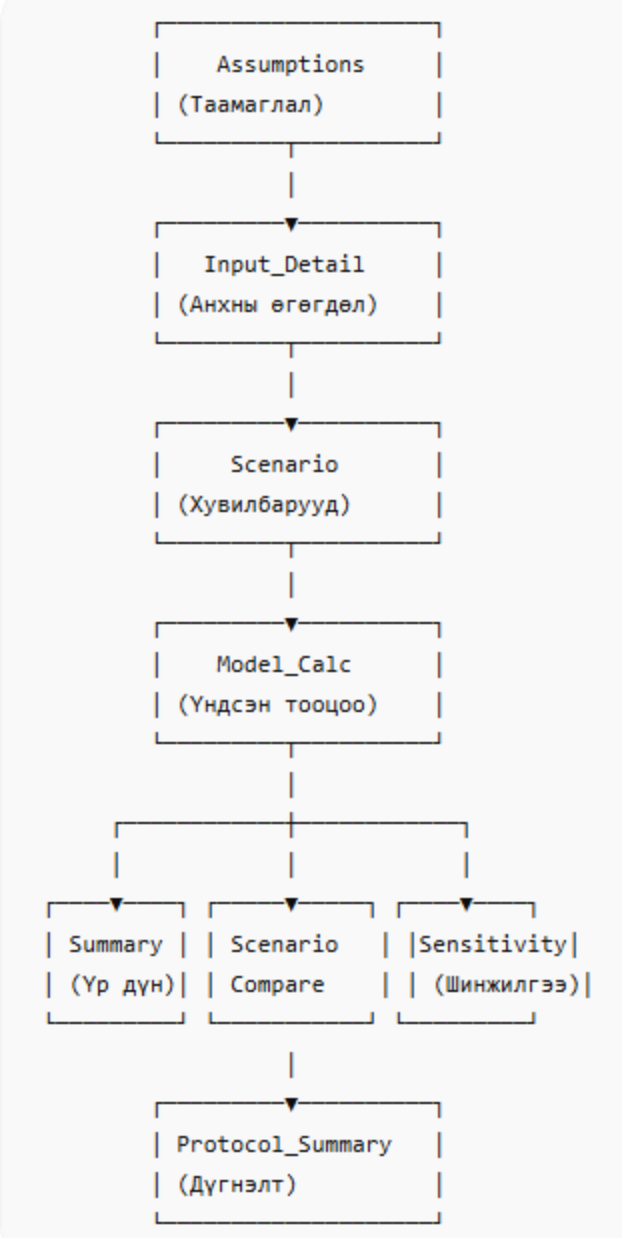
https://docs.google.com/spreadsheets/d/1H-GDoqOVSJYr0iGdbTHBkmsAELqAMxM3/edit?usp=sharing&ouid=118065709125947928253&rtpof=true&sd=true

The model consists of the following main components.

№	Хуудасны нэр	Төрөл (Input/Process/Output)	Үндсэн агуулга	Гүйцэтгэх үүрэг
1	Instructions	-	Загвар ашиглах заавар	Хэрэглэгчийг чиглүүлэх
2	Assumptions	Input	Таамаглал, параметрүүд	Загварын суурь нөхцөл
3	Input_Detail	Input	Анхны өгөгдөл	Судалгааны оролт
4	Scenario	Input/Process	Хувилбарын өгөгдөл	Өөр нөхцөлүүдийг тодорхойлох
5	Protocol_Map	-	Загварын бүтэц	Sheet хоорондын логик холбоо
6	Model_Calc	Process	Үндсэн загвар	Гол тооцоолол
7	Summary	Output	Нэгтгэсэн үр дүн	Ерөнхий дүн
8	Protocol_Summary	Output	Дүгнэлт	Үр дүнгийн товч

№	Хуудасны нэр	Төрөл (Input/Process/Output)	Үндсэн агуулга	Гүйцэтгэх үүрэг
9	Scenario_Compare	Output	Харьцуулалт	Хувилбаруудын ялгаа
10	Sensitivity	Output	Мэдрэмжийн шинжилгээ	Эрсдэлийн үнэлгээ
11	Sources	-	Эх сурвалж	Өгөгдлийн баталгаажуулалт

The table presents the structure of the Microsoft Excel model used in the study, including the purpose of each worksheet and its role in cost estimation. The model is organized into three stages: input data (Input), processing (Process), and output results (Output).



The structure of the Microsoft Excel model used in the study and the data flow are illustrated in the figure above. The model is organized in a logical sequence, starting from input data and assumptions, passing through the core calculation section, and proceeding to result aggregation, scenario analysis, and sensitivity analysis.

3.3.1. Description of the Assumption Sheet

In this study, financial modeling was carried out based on a set of defined underlying assumptions. These assumptions were consolidated in the “Assumption Sheet,” which serves as the source of all input variables in the model.

The Assumption Sheet includes the following key indicators:

- Macroeconomic indicators (e.g., inflation, exchange rate growth)
- Revenue growth rate
- Cost structure
- Interest rate
- Tax rate
- Capital expenditure (CAPEX)
- Working capital assumptions

These assumptions were determined based on:

- Historical data
- Industry benchmarks
- Forward-looking estimates

The Assumption Sheet is directly linked to other components of the model (such as the income statement, cash flow statement, and valuation calculations), and it is structured in such a way that any changes dynamically affect all results.

Therefore, the Assumption Sheet serves as the fundamental foundation of the research model and enables assumption-based analyses such as scenario and sensitivity analysis.

3.3.2. Structure and Description of Input_Detail Data

The primary input data of the financial model used in this study were compiled and structured in the Input_Detail table. This section systematically categorizes all cost-related information associated with the implementation of the TSM standard and serves as the foundational dataset for subsequent calculations.

The Input_Detail table represents all cost elements row by row and includes the following key columns:

- ID – unique identifier of the cost

- TSM protocol – the standard category to which the cost is related
- ESG pillar – classification into Environmental (E), Social (S), and Governance (G)
- Cost item – specific name of the cost
- Category – type of cost (CAPEX, OPEX, compliance, consulting, administrative, etc.)
- Cost timing – frequency of occurrence
- Base cost (2026) – cost amount in the initial year
- Refresh % – percentage of costs that may recur over time
- Description / Source – justification and source of information

This structure enables the analysis of costs from multiple perspectives (ESG, protocol, type, and timing).

Cost Timing Classification

- Recurring – costs that occur annually and increase due to inflation
- Initial only – one-time costs incurred only in the first year
- Initial + Refresh – costs incurred in the initial year and repeated after a certain period

This classification plays an important role in accurately estimating multi-year financial flows.

Cost Classification and Structure

- Capital expenditure (CAPEX) – infrastructure, equipment, and system upgrades
- Operating expenditure (OPEX) – costs related to daily operations
- Compliance costs – costs associated with meeting standards and regulations
- Consulting – external experts, audits, and advisory services
- Administrative – management, training, and office-related expenses

This classification helps define the overall cost structure and supports strategic decision-making.

Application of ESG Classification

Classifying each cost according to ESG (Environmental, Social, Governance) allows:

- Identification of environmental (E) costs
- Evaluation of social (S) impact-related costs
- Differentiation of governance (G)-related investments

Role in the Model (Input Detail)

- Serves as the primary source of all calculation inputs
- Provides the basis for allocating cost flows by year
- Used in NPV and scenario analysis
- Enables analysis at ESG and protocol levels

The Input Detail section is the most critical component of the financial model in this study, forming the basis for accurately defining and systematically calculating the costs of TSM implementation. This structure enables transparency, comparability, and efficient analysis of costs.

3.3.3. Scenario Analysis

In this study, scenario analysis was conducted to evaluate the uncertainty of costs associated with the implementation of the TSM standard and to account for changes in future conditions. The scenario approach aims to determine how financial outcomes vary under different conditions, assess risks, and support decision-making.

Types of Scenarios

The following three main scenarios were developed in the study:

Base Scenario

The base scenario represents the most realistic and highly probable conditions. In this case:

- Costs are implemented according to the initial estimates
- Inflation remains at an average level
- Refresh costs occur as planned
- Implementation proceeds steadily

This scenario was used as a benchmark for comparison with other alternatives.

Optimistic Scenario

The optimistic scenario reflects more favorable conditions:

- Cost growth is lower
- Efficiency improves, and some costs decrease
- Implementation is more effective and completed ahead of schedule
- Refresh costs may decrease or be delayed

This scenario represents the most efficient case of TSM implementation.

Pessimistic Scenario

The pessimistic scenario represents high-risk conditions:

- Cost growth is high
- Inflation increases
- Implementation is delayed, leading to additional costs
- Refresh costs occur more frequently

This scenario was used to evaluate the financial burden under the most unfavorable conditions.

Scenario Variables

The following key variables were used to differentiate the scenarios:

- Cost escalation rate (inflation / escalation rate)
- Refresh cost percentage and frequency
- Implementation efficiency
- Cost structure (CAPEX vs OPEX)

These variables directly affect total costs and financial outcomes.

Calculation Method

For each scenario:

- Data from the Input Detail section were used
- Costs were projected for the period 2026–2030
- Annual cash flows were determined
- NPV (Net Present Value) was calculated using a discounting method

The results of each scenario were compared to evaluate total costs and financial impact.

Comparison and Evaluation

As a result of the scenario analysis, the following were compared:

- Variations in total costs
- Changes in costs by ESG classification
- Differences in financial indicators (such as NPV)

This comparison enabled the identification of the risk range and potential financial outcomes of TSM implementation.

Scenario analysis is an important method for reducing uncertainty in TSM implementation costs and for evaluating potential outcomes under different conditions. The results of the study indicate that cost escalation and implementation efficiency are the most influential factors affecting the final financial outcomes.

3.3.4. Protocol Mapping

In this study, protocol mapping was developed to align the TSM (Towards Sustainable Mining) standard protocols with the company's operations and ESG (Environmental, Social, Governance) pillars. Protocol mapping provides a systematic classification of standard requirements and serves as a foundation for identifying related costs and activities.

Structure of TSM Protocols

The TSM standard consists of various protocols aimed at ensuring sustainable mining practices. The following key protocols were included in the study:

- Tailings management
- Water management
- Climate change management
- Biodiversity conservation
- Community engagement
- Occupational health and safety
- Crisis management
- Ethics and governance

Each protocol includes specific criteria and requirements and allows evaluation of implementation performance.

Alignment with ESG

Each protocol was linked to ESG categories as follows:

- **Environmental (E)**
    - Protocols related to water, tailings, climate, and biodiversity
- **Social (S)**
    - Community engagement, occupational safety, and social impacts

- **Governance (G)**
    - Ethics, transparency, and risk management

This alignment is important for ensuring that the company's sustainability performance meets international ESG standards.

Linking Protocols and Costs

The most important aspect of protocol mapping is linking each protocol to relevant cost elements. This was implemented as follows:

- Analyzing the requirements of each protocol
- Identifying the activities required for implementation
- Recording the associated costs in the Input_Detail section

As a result:

- It becomes possible to identify which protocols require the highest costs
- Evaluate the financial burden of each ESG dimension
- Determine strategic priorities

Role in the Model (Protocol Mapping)

- Classifies costs at the protocol level
- Enables ESG-based analysis
- Incorporates protocol impacts into scenario analysis
- Supports detailed analysis in summary and reporting sections

This mapping establishes a logical link between the Input Detail and Model Calc sections, ensuring data consistency.

Protocol mapping is a key tool for linking TSM standard requirements with company operations and the financial model. This approach enables more precise cost estimation, evaluation of ESG performance, and supports strategic decision-making.

3.3.5. Financial Calculation Model (Model Calc)

The Model Calc section is designed to calculate the costs associated with the implementation of the TSM (Towards Sustainable Mining) standard over time, determine cash flows, and perform financial evaluation. This section uses the data defined in Input Detail to calculate the cost dynamics over the period 2026–2030.

General Structure of Calculation

The following key steps were implemented in the Model Calc section:

- Import cost data from Input Detail
- Allocate costs over time (annually)
- Incorporate the effect of inflation
- Calculate total cost flows
- Determine financial indicators (e.g., NPV)

These steps ensure that the financial model is structured in a systematic and repeatable manner.

Cost Time Allocation

Costs were distributed across years based on the cost timing types defined in the Input Detail section:

- **Recurring costs**
  Occur annually and increase with inflation.
- **Initial only costs**
  Occur once in 2026 only.
- **Initial + Refresh costs**
  Occur in the initial year and recur after a specified period (e.g., 2029).

This approach allows for a more accurate representation of real-world cost flows.

Inflation Calculation

Cost growth was calculated annually using the inflation rate by:

- Increasing base costs (2026) in subsequent years
- Adjusting recurring costs annually
- Applying inflation effects to refresh costs at the time they occur

Cash Flow Calculation

In the Model Calc section, total annual costs were aggregated to determine:

- Annual cost outflow (cash outflow)
- Total cumulative costs

This enables the evaluation of the financial burden of TSM implementation over time.

Financial Evaluation (NPV)

To determine the present value of TSM implementation costs, NPV (Net Present Value) was used:

$NPV = \sum(CF_t / (1 + r)^t)$

Where:

- CF_t – cash flow in year t
- r – discount rate
- t – time (year)

The NPV calculation converts future costs into present value, allowing for the assessment of the real financial burden.

Role in the Model (Model Calc)

- Converts input data into actual cost flows
- Provides baseline calculations for scenario analysis
- Supplies data for summary and reporting sections

- Enables cost analysis at ESG and protocol levels

The Model Calc section is the core of the financial model, processing cost data over time and providing a realistic financial picture. This model serves as an important tool for evaluating long-term TSM implementation costs and supporting strategic decision-making.

3.3.6. Summary

The Summary section consolidates the results of the financial model (Model Calc) and presents the total cost, structure, and temporal changes associated with the implementation of the TSM standard. This section provides key indicators required for decision-making in a clear and concise manner.

Overview of Total Costs

The results show that TSM implementation requires significant costs in the initial year, with cost structures changing over time:

- In the first year (2026), capital expenditure (CAPEX) dominates
- In subsequent years, operating expenditure (OPEX) and recurring costs prevail
- Some costs recur periodically (refresh), increasing total costs

This indicates that TSM implementation requires high initial investment, followed by ongoing operational costs.

Cost Structure

By classification:

- Capital expenditure (CAPEX) – largest share
- Operating expenditure (OPEX) – stable over the long term
- Compliance costs – ongoing costs for meeting standards
- Consulting – higher in the initial phase
- Administrative – relatively smaller but necessary

This structure highlights the financial characteristics of TSM implementation.

ESG Analysis

Cost distribution by ESG classification shows:

- Environmental (E) costs have the highest share
- Dominated by water, tailings, and climate-related costs
- Social (S) costs are moderate
- Governance (G) costs are relatively lower

This indicates that TSM standards require higher investment in environmental areas.

Protocol-Level Analysis

At the protocol level, the highest-cost areas include:

- Tailings management
- Water management
- Climate change management
- Community engagement

These are strategically important areas with the greatest impact on mining operations.

Financial Evaluation

Based on Model Calc:

- Total costs increase steadily over time
- NPV reflects the present value of future costs
- Scenario analysis shows cost growth and efficiency are key drivers

Summary Conclusion

TSM implementation:

- Requires high initial investment

- Leads to long-term operational costs
- Requires more funding in environmental areas
- Has a cost structure concentrated in key strategic protocols

This analysis provides a comprehensive understanding of the financial impact of TSM implementation and supports managerial decision-making.

3.3.7. Protocol Summary

The Protocol Summary section consolidates the financial burden and relative importance of each TSM protocol to identify which areas require more resources.

Cost Comparison by Protocol

Results show:

- Tailings management – highest cost
- Water management – high investment
- Climate change management – increasing over time
- Community engagement – significant social costs

Cost Structure by Protocol

- Some protocols are CAPEX-heavy (e.g., water, tailings)
- Others are OPEX/recurring (e.g., community engagement)
- Compliance and consulting costs are distributed across all protocols

ESG Alignment

- Environmental (E) protocols – highest cost
- Social (S) – moderate
- Governance (G) – lower

Strategic Implications

- High-cost protocols often correspond to high-risk and high-impact areas
- Environmental investments support long-term sustainability
- Social protocols support social license to operate
- Governance improves transparency and trust

Role in the Model

- Aggregates costs at protocol level
- Supports ESG and strategic analysis
- Explains scenario analysis results
- Provides input for Summary and Discussion

Protocol analysis highlights the strategic and financial importance of TSM implementation.

3.3.8. Scenario Comparison

This section compares cost variations under different scenarios.

Comparison Basis

- Base scenario
- Optimistic scenario
- Pessimistic scenario

Cost Comparison

- Optimistic – lowest cost
- Base – moderate
- Pessimistic – highest

Time Dynamics

- Optimistic – slower growth

- Base – stable growth
- Pessimistic – rapid increase

Financial Indicators

- Lowest NPV (highest burden) in pessimistic
- Lower burden in optimistic

ESG & Protocol Impact

- Environmental costs dominate in all scenarios
- High-cost protocols grow faster under risk

Conclusion

- Cost growth and efficiency are key drivers
- Risk significantly increases financial burden
- Efficiency improvements reduce costs

3.3.9. Sensitivity Analysis

Sensitivity analysis evaluates how financial outcomes depend on key variables.

Variables Used

- Inflation rate
- Discount rate
- Refresh cost frequency
- Recurring cost growth

Method

- Variables adjusted by ±10%, ±20%
- Others held constant (ceteris paribus)
- NPV and total cost recalculated

Results

- Inflation → strongest impact on total cost
- Discount rate → strongest impact on NPV
- Refresh → causes cost spikes
- Recurring → major long-term contributor

Conclusion

- Most sensitive variables: inflation & recurring costs
- NPV driven by discount rate
- Refresh costs create periodic shocks

Practical Implications

- Identify key risk drivers
- Improve cost control strategies
- Enhance financial planning
- Reduce uncertainty in decision-making

Sensitivity analysis shows that TSM financial outcomes depend heavily on inflation, discount rate, and recurring costs. Effective management of these factors is critical for ensuring financial sustainability.

CHAPTER 4. CASE STUDY: A MONGOLIAN MINING COMPANY and Assumption Analysis

4.1 Company Overview

- **Erdenet Mining Corporation**

In this study, Erdenet Mining Corporation was selected as a case study representing the mining sector of Mongolia. The company is engaged in the extraction and processing of copper and molybdenum ore and is a strategically important enterprise that contributes significantly to the country's export revenue and state budget.

Erdenet Mining Corporation operates on a large scale with thousands of employees and is considered one of the largest enterprises in the mining sector. Its operations encompass a comprehensive system including mining, processing, tailings management, infrastructure, and environmental management.

From an economic perspective, the company contributes a significant portion of mining export revenues and plays an important role in the stable growth of Mongolia's economy. Due to the scale of its operations, it has a substantial impact on the environment and society, increasing the necessity to implement ESG and sustainable development policies.

In recent years, Erdenet Mining Corporation has begun implementing measures related to environmental protection, occupational safety, and social responsibility, and is gradually integrating ESG principles into its operations. However, full implementation of the international sustainability framework Towards Sustainable Mining (TSM) still requires detailed financial and operational assessment.

Therefore, selecting Erdenet Mining Corporation as a case study enables a practical analysis of the cost structure and financial impact of implementing the TSM framework under real mining conditions, as well as aligning sustainability requirements with a financial model. This directly supports the objectives of the study and enhances its practical relevance.

4.2 Current TSM and Sustainability Practices

Erdenet Mining Corporation has implemented sustainable development principles to a certain extent in its mining operations; however, it has not fully adopted the international standard Towards Sustainable Mining (TSM) and currently operates at a partially compliant level.

The TSM framework is an international standard consisting of nine core protocols designed to systematically evaluate environmental, social, and governance performance in mining companies. It aims to make mining operations more transparent, measurable, and accountable. Therefore, analyzing the company's current practices in alignment with TSM protocols is of significant importance.

4.2.1 Environmental Practices and TSM Protocols

Within environmental management, Erdenet Mining Corporation implements tailings dam monitoring, water resource management, and rehabilitation activities. These operations correspond to the following TSM protocols:

- Tailings Management – ensuring the safety of tailings facilities
- Water Stewardship – monitoring water usage and quality
- Biodiversity Conservation – environmental protection

However, current implementation is primarily operational in nature, and the following TSM requirements are not yet fully integrated:

- Performance indicators
- Continuous improvement systems
- Transparent reporting

4.2.2 Social Practices and TSM Protocols

The company undertakes activities aimed at contributing to local community development and ensuring worker safety. These correspond to the following TSM protocols:

- Indigenous and Community Relationships – community engagement
- Safety and Health – occupational health and safety
- Crisis Management – emergency preparedness

Although the company implements community relations and social programs, the following elements have not yet fully reached TSM standards:

- Stakeholder engagement systems
- Grievance mechanisms
- Measurement of social impact

4.2.3 Governance Practices and TSM Protocols

In terms of governance, Erdenet Mining Corporation complies with legal requirements and implements internal audit and reporting systems. This aligns with the following TSM areas:

- Responsible Supply Chain – supply chain monitoring
- Preventing Child and Forced Labor – human rights
- Governance and transparency (general TSM principles)

However, the following key TSM requirements are not fully developed:

- Performance rating system (A–AAA)
- Third-party verification
- Transparent ESG reporting

Current Level of TSM Implementation

The analysis indicates that while the company's current sustainability practices align with some TSM requirements, the following weaknesses remain:

- Lack of systematization of activities
- Insufficient performance measurement (KPI)
- Limited transparency in reporting
- Incomplete alignment with international standards

Therefore, implementing the TSM framework has strategic importance in:

- Systematizing existing ESG activities
- Improving cost transparency
- Reducing risks

4.3 Assumption Analysis

4.3.1 Cost Drivers and Financial Variables

The following key variables were used in the financial model:

- Number of ESG and environmental staff
- Average employee salary
- Training frequency
- Monitoring frequency
- Number of audits
- Investment amount

These variables are defined as input parameters in the *Assumptions* section of the Excel model and directly influence cost calculations.

4.3.2 Integration with the Financial Model

The Excel financial model developed in this study is structured into the following main components to align TSM requirements with cost structures:

- **Assumptions:** input parameters
- **Scenario:** implementation scenarios
- **Protocol Map:** TSM protocol → cost linkage
- **Model Calculation:** cost computation
- **Summary:** total cost results

In particular, the **"Protocol Map"** serves as the core mechanism linking TSM protocols to financial cost categories, forming the methodological foundation of this study.

This approach of linking TSM requirements to operational costs enables the transformation of sustainability concepts into measurable financial metrics.

The findings show that TSM implementation costs are not uniform but consist of a mix of **CAPEX, OPEX, and compliance costs**, which may vary depending on operational characteristics and management decisions of mining companies.

Thus, modeling TSM protocols in alignment with cost structures is critical for financial planning, risk management, and strategic decision-making in mining companies.

4.3.3 Estimated Cost Structure of TSM Implementation

The cost structure associated with implementing the TSM (Towards Sustainable Mining) framework significantly affects financial burden, resource allocation, and strategic decision-making in mining operations.

Based on the Excel financial model developed in this study, TSM implementation costs were calculated over a **5-year period**, analyzing cost structure, time dynamics, and protocol-level distribution.

Total TSM Cost = CAPEX + OPEX + Compliance + Consulting + Administrative

4.3.4 Total Cost (Financial Output)

From the *Summary* and *Protocol Summary* sheets:

Indicator	**Total (mil.tug)**
First year total cost	9,382.40
5 years total cost	30,186.30
NPV (5 year)	≈ 24,267.9

Table 2. Total Cost (Financial Output)

Insights:

- TSM implementation is not a one-time project but a long-term financial commitment
- Costs are highest in the first year (setup phase)
- OPEX dominates in later years

4.3.5 Time Distribution of Costs

Year	Cost (million MNT)
2026	9,382.40
2027	4,219.90
2028	4,557.60
2029	6,710.40
2030	5,316.00

Table 3. Time Distribution of Costs

- **2026:** CAPEX + initial setup (highest cost)
- **2027–2030:** OPEX + compliance-driven costs
- **2029 increase:** due to expanded monitoring and ESG maturity

4.3.6 Protocol-Level Cost Distribution

Протокол	5 жилийн зардал	Хувь
Safety & Health	5,888.1	19.5%
Community	5,459.7	18.1%
Tailings	4,685.0	15.5%
Climate / Energy	2,879.1	9.5%
ESG cross-functional	2,831.2	9.4%
Water	2,699.6	8.9%
Biodiversity	2,469.3	8.2%
Supply chain	1,573.1	5.2%
Compliance (audit)	1,290.7	4.3%

Table 4. Protocol-Level Cost Distribution

Key points:

- Human-driven costs (Safety, Community) are the highest
- High-risk infrastructure (Tailings) is CAPEX-heavy
- Compliance costs are lowest but strategically important

4.3.7 Cost Structure Analysis

TSM implementation costs consist of:

1. **CAPEX**
    - Concentrated in the first year
    - Includes sensors, monitoring systems, water treatment
    - Long-term assets
2. **OPEX (largest component)**
    - ESG personnel
    - Monitoring
    - Training
    - Community engagement
    - Recurring → main cost driver
3. **Compliance**
    - Audits
    - ESG reporting
    - Certification
    - No direct revenue but:
      → reduces risk + builds investor trust
4. **Consulting**
    - EIA, biodiversity, hydrology
    - High in early stages

5. **Administrative**
    - ESG governance
    - Internal reporting

4.3.8 Key Insights

1. **TSM is not a cost center but a strategic investment**
    - High initial costs
    - Long-term risk reduction
2. **OPEX dominates**
    - ESG implementation is people- and process-driven
    - Requires continuous operations
3. **CAPEX is front-loaded**
    - Infrastructure-heavy protocols (Tailings, Water)
4. **Risk–cost tradeoff**
    - Compliance cost is low
    - But has high strategic value
5. **Uneven cost distribution**
    - Safety + Community ≈ 40%
    - Indicates the social dimension of ESG is the most expensive

The estimated cost structure of TSM implementation clearly demonstrates the financial burden on mining operations. The total cost of **30.2 billion MNT over 5 years** indicates that sustainability implementation is not merely compliance but a strategic investment.

While TSM requires high **CAPEX in the initial phase**, it transitions into an **OPEX-dominated stable cost structure** over time. This highlights the necessity for mining companies to integrate ESG and sustainability requirements into their core operations.

CHAPTER 5. RESULTS AND DISCUSSION

5.1 Key Findings

Using the Excel-based financial model developed in this study, the structure and magnitude of costs associated with the implementation of the Towards Sustainable Mining (TSM) framework were estimated. The model results indicate that TSM implementation generates significant short-term costs in mining operations.

According to the financial model calculations, the total cost of TSM implementation over a five-year period reaches 30,186.3 million MNT, with 9,382.4 million MNT incurred in the first year. This reflects the high level of capital expenditure (CAPEX) required during the initial phase, primarily related to infrastructure development, equipment acquisition, and system implementation.

In subsequent years, the cost structure shifts, with operating expenses (OPEX) and compliance costs becoming dominant. This demonstrates that sustainability implementation is not a one-time effort but rather a continuous process.

Furthermore, the Net Present Value (NPV) over the five-year period is calculated at 24,267.9 million MNT, indicating that TSM implementation has the potential to contribute positively to long-term financial sustainability.

5.2 Key Cost Drivers

The study findings indicate that several key factors influence the cost of TSM implementation:

First, **human resource-related costs** constitute a significant portion of total expenses. The number of employees dedicated to TSM and environmental functions, as well as their salaries, directly affect operating costs (OPEX).

Second, **monitoring and technical infrastructure costs** play a critical role. Systems related to tailings management and water management impact both CAPEX and OPEX.

Third, **compliance costs related to auditing and reporting** are an essential component of sustainability implementation. These costs are aimed at enhancing transparency and accountability within the organization.

Fourth, **consulting costs** are relatively higher during the initial phase of implementation.

Therefore, TSM implementation costs are determined by the combined influence of multiple factors, including human resources, technology, auditing, and consulting services.

5.3 Compliance Costs and Long-Term Benefits

Compliance costs are an integral part of TSM implementation and generate additional expenses in the short term. However, in the long term, they produce several positive outcomes:

- Reduction of legal and regulatory risks
- Minimization of penalties and operational disruptions
- Increased stakeholder trust
- Improved investment environment

In alignment with the financial model results, compliance costs account for a certain portion of total costs but have the potential to generate economic benefits over time through risk reduction.

5.4 Comparison with International Practices

When comparing the study results with international mining practices, similar trends are observed.

International mining companies typically incur high initial investments when implementing TSM and sustainability programs, followed by ongoing operational and compliance costs in later stages.

The findings of this study are consistent with these trends, indicating that TSM implementation aligns with international best practices.

5.5 Overall Financial Evaluation

The financial model results indicate that while TSM implementation increases costs in the short term, it has the potential to generate economic benefits in the long term.

The positive NPV suggests that sustainability implementation can enhance the long-term value of the company.

Therefore, TSM implementation can be considered a strategic investment.

5.6 General Discussion

The findings of this study demonstrate that implementing sustainability frameworks is not merely an additional cost burden but rather a strategic decision that creates long-term value.

Although TSM implementation imposes financial pressure in the initial phase, it generates multiple benefits, including risk reduction, improved operational stability, and increased investor confidence.

Therefore, it is essential for mining companies to integrate sustainability frameworks into their financial planning and modeling processes.

CHAPTER 6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study identified the costs of TSM implementation using a financial model and analyzed its impact on mining company operations.

The results show that TSM implementation requires a total cost of 30,186.3 million MNT over a five-year period, with the highest cost burden occurring in the first year. However, the positive NPV of 24,267.9 million MNT indicates that the implementation is economically beneficial in the long term.

Therefore, TSM implementation can be regarded as a strategic investment.

In conclusion, this study demonstrates that implementing sustainability frameworks in the mining sector is not only environmentally and socially significant but also a financially justified strategic decision. By proposing a methodology for estimating and evaluating TSM implementation costs, the study provides practical contributions to decision-making processes in mining companies.

6.2 Recommendations for Companies

Based on the findings of this study, it is concluded that mining companies need to adopt a strategic and integrated approach to effectively implement the TSM and ESG frameworks. In this regard, the following key recommendations are proposed:

- **Integrating sustainability costs into financial strategy**
  The results of the financial model developed in this study indicate that TSM implementation requires significant capital expenditure (CAPEX) during the initial phase and subsequently transitions into recurring operational expenditure (OPEX). Therefore, companies should not treat sustainability costs as isolated expenses but rather systematically incorporate them into long-term financial strategies, investment planning, and cash flow management processes.

- **Strengthening organizational capacity and human resource development**
  The successful implementation of TSM and ESG frameworks largely depends on internal organizational capacity and the professional competencies of human resources. Accordingly, companies should establish dedicated ESG teams and implement continuous training and capacity-building programs. This will directly enhance implementation efficiency and contribute to cost optimization.

- **Developing institutionalized stakeholder engagement mechanisms**
  Establishing sustainable, transparent, and two-way communication with stakeholders—including local communities, government authorities, investors, and employees—is fundamental to securing a “social license to operate.” Therefore, it is necessary to systematize stakeholder engagement processes, strengthen grievance mechanisms, and refine communication strategies.

- **Enhancing data-driven management and monitoring systems**
  To effectively measure, monitor, and improve ESG and TSM performance, companies must establish data-driven management systems. This includes defining key performance indicators (KPIs), implementing internal monitoring and evaluation systems, and improving the quality and transparency of reporting in line with international standards.

6.3 Policy Recommendations for Mongolia

The findings of this study suggest that the role of government policy and the regulatory environment is critical in facilitating the effective adoption of TSM and ESG frameworks in the mining sector. Accordingly, the following policy recommendations are proposed:

- **Establishing a regulatory environment that supports international sustainability standards**
  Integrating international standards such as TSM into national mining policies and legal frameworks will enhance industry competitiveness and promote responsible mining practices.
- **Improving transparency and standardization of ESG reporting**
  Standardizing ESG reporting and increasing transparency will strengthen investor confidence and improve the ability of companies to compete in international markets.
- **Developing financial mechanisms to support sustainable mining**
  Providing economic incentives—such as tax benefits, green financing, and concessional loans—to companies investing in sustainable development initiatives will play a strategic role in accelerating implementation.

6.4 Study Limitation

This study is based on a single case study, which imposes certain limitations on the generalizability of the findings to the broader mining sector. Additionally, some of the data used in the analysis were developed based on assumptions due to constraints in data availability. Therefore, the results should be interpreted with these limitations in mind.

6.5 Future Research Directions

Future research should further explore the following areas:

- Developing more advanced financial models incorporating indicators such as NPV (Net Present Value), IRR (Internal Rate of Return), and risk-adjusted evaluation metrics
- Expanding the analysis by incorporating data from multiple mining companies to enhance generalizability

- Developing dynamic models based on real-time data to improve accuracy
- Examining the relationship between TSM implementation costs and long-term economic, social, and environmental benefits

Expanding research in these directions will contribute to a deeper and more comprehensive understanding of the financial and strategic implications of sustainability policies in the mining sector.

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