Impact of rail freight on the financial viability of coal mining companies in Mpumalanga, South Africa

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ABSTRACT

The study explored how the efficiency of rail freight affects the financial health of coal mining companies in Mpumalanga, South Africa. It aimed to determine whether lower performance in the Transnet Freight Rail (TFR) system has a negative impact on key financial indicators such as revenue, earnings before interest and tax (EBIT), and net profit margins (NPM). The research adds to the understanding of how transport performance influences the long-term sustainability and profitability of coal mining businesses.

The study used a quantitative research approach based on secondary data from three listed coal mining companies. The analysis included correlation tests, trend analysis, and linear regression to explore the relationships in the data. Rail efficiency was measured by the total amount of coal transported by rail, while financial performance was evaluated using reported figures for revenue, EBIT, and net profit margins (NPM).

The findings indicate a strong positive relationship between rail freight efficiency and financial performance. Inefficiencies in the freight rail network were shown to result in higher costs and lower profit margins for mining companies. The results affirm theoretical insights from Transaction Cost Economics and Supply Chain Management theory, both of which emphasise the importance of reliable transport infrastructure for efficient operations and strong financial outcomes.

The study focused on three large mining companies and did not include factors like coal prices or exchange rates, which may also affect financial results. Even with these limitations, the research offers recommendations for mining companies and policymakers. These include investing in rail infrastructure, improved scenario planning, and the adoption of integrated logistics strategies to support the long-term success of the coal sector.

CHAPTER 1: INTRODUCTION

1.1 Chapter 1 introduction

The coal mining industry is central to South Africa's economy, particularly in Mpumalanga, the country's largest coal-producing province. The region's mines depend on efficient freight logistics to transport coal over distances of 400–600 kilometres to export terminals such as the Richards Bay Coal Terminal (RBCT). Logistics efficiency, especially in rail transport, plays a critical role in determining the financial viability of these mining operations.

Transnet Freight Rail (TFR) has historically been the backbone of this transport network, offering cost-effective and scalable coal haulage. However, in recent years, rail inefficiencies—stemming from infrastructure constraints, locomotive shortages, and operational disruptions—have raised freight costs and limited export capacity. As highlighted by Havenga et al. (2023), rail-borne coal exports have declined to their lowest levels in three decades, underscoring the growing logistical and financial strain on mining companies.

This study examines how freight costs—a broader term encompassing both rail and road transport expenses—affect the financial viability of coal mining companies in Mpumalanga. By analysing the relationship between logistics performance and financial outcomes, the research seeks to provide evidence that can guide corporate strategy and infrastructure planning.

The chapter proceeds as follows: Section 1.1 outlines the statement of purpose; Section 1.2 provides background context; Section 1.3 presents the problem statement; Sections 1.4 and 1.5 state the objectives and research questions; Section 1.6 explains the rationale; Section 1.7 defines the delimitations; and Section 1.8 presents the study assumptions.

1.2 Statement of purpose

The effectiveness of logistics system is inherently connected to the financial performance of coal mining companies. In Mpumalanga, the largest coal-producing province in South Africa, coal hauling activities that involve the haulage of coal between mines and export terminals, often involving distances of up to 400-600 kilometres, has edged toward the operational and commercial feasibility of the industry.

The purpose of this study is to explore how the cost of logistics affects financial feasibility of coal mining industry in Mpumalanga, South Africa.

1.3 Background

Efficient logistics systems are a cornerstone of industrial competitiveness and financial sustainability across many sectors, particularly in resource-dependent economies. In industries such as mining, where bulk commodities must be transported over long distances, logistics efficiency and transport infrastructure directly influence profitability, cost structures, and operational resilience. Rail freight, in particular, is globally recognised as the most cost-effective and environmentally sustainable mode for moving large volumes of minerals and energy resources, offering significant economies of scale compared to road transport (Notteboom & Rodrigue, 2008).

Within the South African context, the coal mining industry relies heavily on its ability to move vast coal reserves from inland mines to coastal export facilities. This logistics chain is vital for maintaining the sector's contribution to national revenue and employment. The Richards Bay Coal Line (RBCL), described by De Bod and Havenga (2016), serves as the central artery of this system, linking the coalfields of Mpumalanga—the country's largest coal-producing province—with the Richards Bay Coal Terminal (RBCT). For decades, the rail network has enabled cost-effective long-distance transport that aligns with both commercial efficiency and environmental objectives. However, in recent years the performance of the freight rail network has been taken to task. Van Jaarsveld et al. (2013) and Pooe and Mathu (2011) identified an increase in complexities in logistics chain such as infrastructure congestion, shortage of rolling stocks and difficulty to coordinate major stakeholders. Although such problems have been increasingly associated with the rise of transport prices and time in the popular discourse, the nature of the connection between rail performance and financial performance in the coal industry has not yet been studied thoroughly.

Exports of coal by rail have displayed a downward trend with Havenga et al. (2023) indicating that rail-borne coal exports declined to 47.21 million tons in 2023, which is the lowest in more than thirty years. The reasons for this decline are multifaceted and may include operational, technical, and broader systemic factors. Nevertheless, the reduction in throughput has prompted questions about the broader economic and financial implications for coal producers that rely on this infrastructure.

Geographical constraints further amplify the importance of rail. As Coaltech Research Association (2009) and Pieterse et al. (2016) note, most coal mines in Mpumalanga are located 400 to 600 kilometres from major ports, limiting the feasibility of road-based alternatives. Where road transport is used, it tends to introduce cost pressures and environmental considerations that complicate operational planning.

While the strategic role of logistics in shaping business outcomes is well-recognised in supply chain literature, the coal sector in South Africa presents a unique context in which this relationship warrants further empirical investigation. Christopher (2016) identifies logistics efficiency as a key driver of competitiveness, particularly in sectors with narrow margins and high volumes. Similarly, Mentzer et al. (2001) emphasize the importance of integrated logistics management in reducing risk and supporting financial performance.

Although several reports and industry observations suggest a link between rail system constraints and increased logistics costs, there is limited firm-level analysis to assess how these dynamics influence financial indicators such as earnings, operational costs, or revenue. This research seeks to fill that gap by exploring the association between rail freight trends and the financial viability of JSE-listed coal mining firms operating in Mpumalanga.

In doing so, the study does not presuppose a causal relationship but rather aims to assess whether such a relationship exists, and to what extent. The findings may inform both business strategy and infrastructure planning within the broader context of South Africa's coal export economy.

1.4 Problem statement

Mpumalanga is heavily reliant on the coal mining sector as most of the economic activities in the region are one way or the other linked to that industry. Because of the geographical position of the region, the industry has always relied on the state logistic company, Transnet, for taking its product to the end user or to port (Etienne & Lochner, 2025; Pooe & Mathu, 2011). Unfortunately, as noted by Havenga et al. (2023) and Boye et al. (2023), Transnet has been going through operational challenges that have limited its ability to service its customers among them, the coal sector in Mpumalanga. In fact, there are suggestions in the popular press that inefficiencies linked to Transnet Freight Rail (TFR) may negatively impact the financial viability of the coal mining sector in Mpumalanga (Mining Weekly, 2019; Reuters, 2025; SABC News, 2023). This is a major problem for the country as the sector directly employs around 48,000 people and supports approximately 150,000 indirect jobs Minerals Council South Africa (2024). Furthermore, moving the transportation of coal to road would threaten the sustainability of mining companies and the broader economic stability of the region (Havenga J. et al., 2023; Minerals Council South Africa., 2024).

This study aims to assess how logistical challenges, particularly those related to Transnet's rail operations, are affecting key financial outcomes of coal mining companies in Mpumalanga. By investigating the relationship between rail freight transportation and key financial metrics, such as profitability, this study seeks to provide empirical evidence that can inform strategies for improving logistical operations.

1.5 Research objectives

This study investigates the relationship between logistics and the financial viability of coal mining companies in Mpumalanga, South Africa. The objectives are therefore:

- To evaluate the impact of transportation costs on the profitability of coal mining companies in Mpumalanga, South Africa.
- To investigate the trends (trend analysis) between annual production changes and transportation costs over time within the coal mining sector.

1.6 Research questions

Based on the identified research objectives, the following research questions have been formulated:

- What is the impact of transportation costs on the profitability of coal mining companies in Mpumalanga, South Africa?
- What is the relationship between the annual production changes and transportation costs over time in the coal mining sector?

1.7 Rationale of the study and significance of the study

1.7.1 Rationale

Efficient freight logistics are essential to the financial sustainability of mining operations. In South Africa, coal producers in Mpumalanga depend predominantly on Transnet Freight Rail (TFR) to move coal to export terminals. However, persistent inefficiencies—such as locomotive shortages, network congestion, and infrastructure deterioration—have increasingly disrupted coal transport. These challenges have translated into higher freight costs, reduced export volumes, and declining profitability across the sector. The rationale for this study is to investigate how these logistics inefficiencies affect the financial viability of coal mining companies. While public discourse and industry reports frequently highlight Transnet's underperformance, limited empirical evidence exists to quantify the financial consequences of these inefficiencies at firm level. By analysing measurable relationships between freight costs, production volumes, and profitability indicators, this study provides a data-driven understanding of how logistics performance shapes the financial sustainability of coal mining firms in Mpumalanga.

1.7.2 Significance and contribution

This study makes several important contributions to theory, practice, policy, and future research:

1. **Theoretical contribution**

   The study contributes to the body of knowledge on logistics and supply chain management by empirically validating the relationship between logistics efficiency and financial performance in a heavy-industry context. Using the lenses of Transaction Cost Economics (TCE) and Supply Chain Management (SCM) Theory, the findings demonstrate that inefficiencies in the freight system increase operational costs and erode profitability. This provides quantitative support for the theoretical proposition that transport performance is a key determinant of firm-level financial viability in bulk commodity industries.

2. Practical contribution

The findings offer actionable insights for coal mining companies into cost management and operational strategy. The regression results reveal that rising transportation costs have a statistically significant negative effect on profitability ($\beta = -0.612$, $p < 0.01$), while improvements in production volume and logistics efficiency lower per-unit transport costs ($\beta = -0.121$, $p < 0.01$). These findings suggest that investment in logistics integration—such as private rail sidings, coordinated scheduling, and digital tracking systems—can enhance production efficiency and profitability despite external constraints.

3. Policy contribution

The study provides empirical evidence that can inform infrastructure and transport policy at the national level. The demonstrated link between declining rail performance and financial strain in the coal sector highlights the need for targeted policy interventions, including public–private partnerships, increased investment in rail infrastructure, and performance accountability within Transnet Freight Rail. These findings can guide policymakers in balancing energy security, export competitiveness, and sustainable transport development.

4. Contribution to future research

The study establishes a quantitative framework for assessing the economic impacts of logistics inefficiency, which future researchers can replicate or expand to other sectors such as iron ore, agriculture, or manufacturing. By isolating logistics performance as a measurable independent variable, this research opens pathways for comparative analyses across industries or regions and for integrating environmental costs into financial performance models.

Therefore, this study not only clarifies *why* logistics inefficiencies matter but also *how* they affect financial outcomes. It bridges the gap between logistics theory and financial analysis, providing practical and policy-relevant insights that support the long-term competitiveness of South Africa's coal mining sector.

1.8 Delimitations of the study

This study is specifically focused on the coal mining sector in Mpumalanga, South Africa, and examines the impact of rail freight inefficiencies on the financial viability of coal mining companies within this region.

1.9 Assumptions

This study assumes the following:

- Impact of Rail Freight Inefficiencies: Rail freight inefficiencies linked to Transnet significantly affect the financial viability of coal mining companies, influencing transportation costs, profitability, production efficiency, and economies of scale. This study assumes that inefficiencies in operations in the Transnet Freight Rail Company; including delays, underperformances or failure to deliver contracted volumes, cause major measurable negative effects on the financial performance of coal mining firms in Mpumalanga. Experiential evidence reveals that inefficient supply chains cost more to transport and further interrupt delivery timelines in addition to diminishing customer satisfaction levels, which hampers financial performance (revenue, margins, profitability), among others.

  In this case Havenga J. et al. (2023) indicate that inadequate performance within South Africa freight rail network has caused the escalation of logistics cost associated with the exporting activities in the mining industry. In like regard, Simchi-Levi et al. (1999), highlights the relationship between logistic system upheavals and the cost structure and financial stability. continuity in transportation Chopra (2017) make it clear that stable transportation is one of the priorities in maintaining the efficiency and financial stability of the supply chain.

  The study considers this assumption to have a key role in its analytical framework because it builds the connection between logistical performance (independent variable) and financial viability (dependent variable), thereby justifying the use of regression analysis and informing the structure of the research model.

- Rail Remains the Dominant and Most Economical Mode of Coal Transport: It is also assumed that Rail is the choice and most cost-effective method of transporting coal, which is mined in centres of mining activity in Mpumalanga to export facilities such as the Richards Bay Coal terminal (RBCT).

  The rationale behind this assumption is the scholarly literature that has repeatedly indicated that rail transport is the most efficient and scalable mode that carries bulk commodities especially in long distances. Notteboom and Rodrigue (2008) and Havenga et al. (2023) state that rail networks have high economies of scale, and freight costs are cheaper on a per-ton basis than a road-based alternative.

  Moreover, the Minerals Council South Africa (2024) warns that the resulting increasing use of road freight, by virtue of its inefficient rail logistics, has had the effect of inflating the logistic cost to mining companies by a considerable margin, besides exerting an unsustainable strain on the road infrastructure used by citizens to commute and go about their daily works.

1.10 Chapter 1 conclusion

This chapter introduced the foundation of the study by outlining the context, purpose, and structure of the research. It established that the financial viability of South Africa's coal mining sector—particularly in Mpumalanga—is intricately linked to the efficiency of its logistics systems, most notably Transnet Freight Rail. The discussion demonstrated that rail inefficiencies have created substantial financial and operational challenges for mining companies, manifesting in increased freight costs, lower profitability, and reduced production efficiency.

The chapter also identified the key problem motivating this research: the lack of empirical evidence quantifying the financial impact of rail logistics inefficiencies on coal mining companies. To address this gap, the study's objectives and research questions were defined, focusing on the relationship between transportation costs, production trends, and profitability. The rationale and significance of the study were articulated, emphasizing its contribution to logistics theory, corporate practice, policy formulation, and future academic inquiry.

By situating the research within the broader context of logistics and supply chain theory, the chapter laid the conceptual groundwork for the subsequent analysis. The next chapter—the Literature Review—builds on this foundation by exploring relevant theoretical frameworks and empirical studies, further clarifying the relationship between logistics performance and financial viability in the coal mining industry.

CHAPTER 2: LITERATURE REVIEW:THEORATICAL AND CONCEPTUAL FRAMEWORK

2.1 Chapter 2 introduction

This chapter presents the theoretical and conceptual foundations of the study. It explains the theories underpinning the research, reviews empirical studies related to logistics performance and financial viability in the coal mining sector, and concludes with a conceptual framework linking these theories to the study's research problem, objectives, and hypotheses.

A multi-theory framework combining Transaction Cost Economics (TCE) and Supply Chain Management (SCM) theory is adopted. This approach offers broader explanatory power than a single theoretical model, as it captures both the strategic decisions firms make to minimize cost and uncertainty (TCE) and the operational processes that enhance efficiency and performance (SCM).

The chapter is structured as follows: Section 2.2 discusses the central role of Transnet in South Africa's freight logistics system; Section 2.3 explores cost management dynamics in the coal sector; Section 2.4 explains infrastructure and supply chain management; Section 2.5 develops the multi-theory framework; Section 2.6 reviews relevant empirical studies; and Section 2.7 presents the conceptual framework underpinning this research.

2.2 The central role of Transnet in South Africa's freight logistics system

Transnet Freight Rail (TFR), a division of Transnet SOC Ltd, is central to South Africa's bulk freight logistics system, particularly in industries such as coal mining, steel production, and agriculture. Co-ordinating more than 20 000 km of rail infrastructure, TFR links inland production centres with major export ports, such as Richards Bay, Durban, and Port Elizabeth (Havenga J. et al., 2023; Phaladi et al., 2019).

Rail transport is often the primary economic means of transporting the coal mined in the coal mining industry in Mpumalanga more so than a question of the desirable mode of transport. Regarding coal transportation, rail is cost-efficient and has the capacity to compete with road due to the high-volume, low margin of coal transportation (Zonailo, 2023; Huttunen, 2023). Particularly the Richards Bay Coal Line: it facilitates the export of coal, which brings billions of foreign revenues per year to the South African economy (Steyn & Minnitt, 2010; De Bod & Havenga, 2016)

Notwithstanding its importance, Transnet has been experiencing many operational issues such as infrastructure degradation, old rolling stock, capacity issues, and poor scheduling procedures. As Stander & Pienaar (2002) and Madubanya & Akinlabi (2016) have pointed out, the worsening performance in rail transport has seen considerable volumes returning to rail traffic being shifted to roads, indicating more profound underlying structural weaknesses in Transnet rail operations, with adverse implications into the freight customers.

Such operational inefficiency has taken the form of reduced volumes on rail, losses by exporters, and increased dependence on expensive and environmentally unfriendly road transport. According to Madubanya & Akinlabi (2016), freight volumes intercepted by road substitutes are not only a burden to the roads and increase carbon emissions but also increase the expense of the supply chains across the mining industry. In a similar fashion, Havenga J. et al. (2023) attribute direct millisecond losses in export revenue directly to subpar rail volumes, a fact that proves the financial impact of Transnet failure-to-perform on coal exporters.

The fact that Transnet controls the bulk freight rail in South Africa in a monopolistic way means that its performance has a direct implication on the financial stability and competitiveness of resource-based industries in the country worldwide. Therefore, any comprehensive logistics improvement strategy must prioritize modernizing and stabilizing Transnet's operations (Havenga J. et al., 2023; Phaladi et al., 2019).

2.3 The importance of cost management in the coal mining sector

Cost management has been a key success criterion in coal mining business a sector whose operations are not only capital intensive but are highly susceptible to the fluctuating nature of the global commodity markets. It is necessary to apply strict cost control to provide financial strength, profitability and sustainability in this environment. Cost management helps companies deal with positive force in the event of market slumps, regulatory demands, and business continuity (Minerals Council South Africa, 2024; Budeba et al., 2015).

This cost management is more significant due to the cyclical coal prices. Firms operating on low operating cost and lean cost structure are capable of continually producing during low international demand periods. According to the research conducted by Tilton (2003) and Humphreys (2015), high-cost producers will be the first to leave markets during the writing of commodities therefore cost competitiveness is an important survival strategy within the industry.

Some of the major cost items involved in coal mining are energy, labour, equipment, compliance and logistics. Logistics is one of them that has in particular become a burning issue as South Africa bulk rail infrastructure is falling in performance. Following inefficiencies in Transnet Freight Rail (TFR), this has resulted in a shift to road transport which has increased the delivery costs as it is very expensive and, in some cases, the delivery costs form over 50 percent of the total costs incurred in delivering coal Minerals Council South Africa (2024).

There are also emerging cost pressures of environmental compliance. Companies must now make substantial investments in stopping emissions, post-mining recovery, and wider ESG (Environmental, Social, Governance) measures to meet the high standards of sustainability being practiced world-wide (Eberhard, 2011; McCormick et al., 2005).

To mitigate these risks, firms are deploying predictive analytics, digital tracking, and real-time supply-chain modelling to identify cost-reduction opportunities (Simchi-Levi et al., 1999; Botin & Vergara, 2015). Thus, effective cost management is not merely an operational concern—it is a strategic pillar for financial resilience in the coal sector.

2.4 Infrastructure and supply chain management

Building on the previous section, which highlighted the strategic importance of cost management in ensuring financial resilience, it becomes evident that infrastructure and logistics systems—particularly rail transport—constitute one of the most critical and volatile external cost drivers in South Africa's coal mining sector. While internal cost controls (e.g., labour, energy, compliance) are essential, the sector's exposure to structural inefficiencies in the national logistics ecosystem has emerged as a primary factor driving up operational expenditure and threatening financial viability.

Logistics-related costs have grown to represent a substantial and escalating share of total production costs. Research by Havenga et al. (2023) indicates that deteriorating rail performance—especially at Transnet Freight Rail (TFR)—has led to significant cost escalations, with some mining companies now reporting that logistics costs account for over 50% of the total delivered cost of coal. These are not just a problem of operational inefficiency; they are strategic financial risks that have a direct bearing on the capacity of firms to maintain margins, allocate capital efficiently and stay competitive globally.

These have been exacerbated by infrastructure brittleness, such as aging rail networks, port capacity restrictions, choked road alternatives and so on. According to Havenga et al. (2023), Transnet coal rail network reported underperformance (close to 30 per cent) in 2022 against 2019 driven by network congestion, vandalism, and a shortage of locomotives. Studies show that such weaknesses are especially detrimental to a business such as coal mining, where late deliveries lead to foreign exchange loss and unused production capacity (De Bod & Havenga, 2016; Mathu, 2014).

Theoretical models from Logistics Theory (Christopher & Peck, 2004; Gunasekaran & Ngai, 2004) support these empirical patterns, suggesting that weaknesses in transport infrastructure cascade through the supply chain, resulting in stockpiling, missed deliveries, cost volatility, and ultimately financial underperformance.

Coal producers that have adopted integrated logistics strategies—such as investing in private sidings, collaborating with freight providers, and deploying real-time transport monitoring—have been better able to contain these risks. Empirical evidence from prior research by Botha and Badenhorst-Weiss (2019) supports the view that hese firms have fewer costs fluctuations and better resilience. Conversely, those companies that do not possess such strategic capabilities are still prone to such frequent interruptions and soaring costs.

Finally, logistics and infrastructure management should be regarded a fundamental pillar of cost control strategy, and not a marginal operation issue. Previous studies have highlighted that the persistent rail and port challenges in South Africa require a comprehensive transformation of the national supply chain system. Scholars such as Zeng et al. (2021) and Wincewicz-Bosy et al. (2021) emphasize the need for stronger coordination between the public and private sectors, increased infrastructure investment aligned with industrial policy, and greater digitisation of logistics and planning. Similarly, Cawood (2011) argued that only such systemic reforms would enable the mining industry to restore cost competitiveness and ensure its long-term viability.

Thus, infrastructure investment and supply-chain coordination are essential for enhancing the long-term cost competitiveness of South Africa's coal industry.

2.5 Multi-Theory Framework: Transaction Cost Economics (TCE) and Supply Chain Management (SCM)

2.5.1 Rationale for a Multi-Theory Approach

A single theoretical lens cannot adequately explain the multifaceted relationship between logistics inefficiencies and financial performance. The Transaction Cost Economics (TCE) framework focuses on cost minimization and uncertainty reduction, while the Supply Chain Management (SCM) theory emphasizes coordination, integration, and responsiveness.

By integrating both, this study captures the dual nature of the problem: TCE explains why firms choose specific logistics structures under uncertainty (e.g., internalizing or outsourcing logistics), while SCM explains how effective coordination and integration within those structures enhance performance.

2.5.2 Transaction Cost Economics (TCE)

First introduced by Oliver Williamson (1985), Transaction Cost Economics (TCE) describes how organizations make decisions about whether to engage in transactions in the market or transfer within their own organisations depending on minimisation of the transaction costs of economic exchanges. Such costs are search costs and information costs, bargaining and negotiation costs and monitoring/ enforcing costs (Williamson, 1985; Rindfleisch & Heide, 1997).

Considering the increasing delays, volatility and uncertainty in the coal mining supply chain because of Transnet Freight Rail (TFR) underperformance, TCE offers a proper rationale to explain the structural choice by players in the coal mining supply chain. Businesses, which invest in owning their own rail sidings or locking into long-term haulage arrangements do so to pursue the objective of less uncertainty and to have a greater degree of control over key logistical operations Groenewegen et al. (2010). Some companies also choose road freight as the alternative even in cases where the cost per ton is higher because of avoidance of penalty cost of export delays, thereby lowering the overall transaction costs, even though not unit costs.

Empirical evidence from previous studies, including Groenewegen et al. (2010), underscores the practical relevance of TCE in this context. Firms that have implemented structural strategies such as developing private rail sidings, entering long-term haulage agreements, or selectively utilising road transport have demonstrated reduced earnings volatility and increased resilience to systemic logistical disruptions. These findings reinforce the applicability of TCE as a cost management framework in environments characterised by logistics-based inefficiencies.

Accordingly, TCE underpins Objective 1 — to evaluate the impact of transportation costs on the profitability of coal mining companies in Mpumalanga. It offers a theoretical rationale for understanding how logistical inefficiencies heighten transaction costs, thereby diminishing profitability and overall financial viability.

2.5.3 Supply Chain Management (SCM) Theory

The SCM theory can be traced to the operations and logistics literature of the 1990s as a continuation of previously developed logistics frameworks, into a more comprehensive, strategic means of value chain coordination (Mentzer et al., 2001; Christopher, 2016). Fundamentally, SCM is about synchronization of information, materials and money flow among various parties within a supply network to minimize cost, maximize responsiveness and overall performance.

When taken to the Mpumalanga coal industry, the SCM theory will show why certain companies can attain a higher level of cost effectiveness and delivery reliability due to coordinated logistics strategies, online locator services and cooperation to schedule freight. These operations fall in line with the theory stressing on visibility, coordination, and agility through the entire supply chain Christopher & Peck (2004).

SCM theory emphasizes coordination, collaboration, and visibility across supply networks to enhance efficiency, responsiveness, and overall performance (Mentzer et al., 2001; Christopher, 2016). In the context of the coal mining sector, SCM explains how firms can mitigate logistical risks by integrating production planning with transport scheduling, adopting digital freight platforms, sharing infrastructure, and fostering cross-organizational collaboration with logistics providers.

Companies that apply SCM principles—through digital freight systems, shared resources, and synchronized logistics and production planning—are better positioned to control cost variability, prevent bottlenecks, and sustain consistent growth despite external infrastructure constraints. By improving coordination and information flow across the supply chain, these practices directly influence production efficiency and cost control.

Accordingly, SCM theory supports Objective 2 — to investigate the relationship between annual production changes and transportation costs over time. It provides a theoretical rationale for understanding how coordinated supply chain activities and efficient information management can reduce logistical inefficiencies, stabilise production levels, and strengthen the overall financial performance of coal mining firms.

2.5.4 Complementarity of TCE and SCM

TCE and SCM complement each other in explaining the relationship between logistics performance and financial viability. TCE addresses the strategic dimension — how firms structure and govern transactions to reduce uncertainty, manage risk, and minimise cost exposure. In contrast, SCM focuses on the operational dimension — how firms coordinate processes, resources, and information flows to improve efficiency, responsiveness, and supply chain resilience.

Together, these theories provide a comprehensive framework that explains both the causal mechanisms (why logistics inefficiencies negatively affect profitability) and the adaptive responses (how firms mitigate these inefficiencies through structural and operational strategies). Within this integrated perspective, TCE elucidates boundary decisions — such as whether to outsource or internalise logistics functions — while SCM highlights the importance of collaborative coordination, information visibility, and flexibility in managing logistics challenges.

Collectively, these perspectives offer a strategic lens for understanding how South African coal firms manage and control rising logistics costs. They reinforce that cost management in the coal mining sector is deeply intertwined with supply chain structure, governance, and infrastructure performance, thus providing a unified theoretical foundation for this study.

2.6 Empirical Studies

This section reviews empirical literature relevant to the study’s two main objectives:

1. To evaluate the impact of transportation costs on the profitability of coal mining companies in Mpumalanga, South Africa.
2. To examine the relationship between annual production trends and transportation costs over time in the coal mining sector.

The review is thematically structured to align with these objectives. Each subsection summarises prior studies, compares their purpose, data, and key findings, and identifies gaps that this study addresses.

2.6.1 The Impact of Transportation Costs on the Profitability of Coal Mining Companies

Transportation costs are a significant determinant of profitability in bulk commodity sectors, particularly in mining. High freight costs, inefficiencies, and unreliable logistics systems reduce export competitiveness and firm profitability.

Havenga et al. (2023) conducted a macroeconomic modelling study of South Africa's freight network and found that rising transport costs substantially reduced profit margins for mining exports, especially coal. De Bod and Havenga (2016) applied a longitudinal cost analysis on coal freight flows and showed that inefficiencies in Transnet Freight Rail (TFR) elevated the cost per tonne delivered, directly impacting profitability.

At a micro level, Botha and Badenhorst-Weiss (2019) used case studies of mining firms and revealed that persistent rail underperformance forced companies to use road transport alternatives, which increased total logistics costs by up to 60%. Globally, Hummels (2007) and Jaffee (2019) linked transport cost escalation to decreased competitiveness in resource-based economies, emphasising the global importance of logistics efficiency in sustaining firm performance.

South African studies tend to focus on state-controlled logistics inefficiencies (Havenga et al., 2023; De Bod & Havenga, 2016), while international research highlights market efficiency and private-sector adaptation (Hummels, 2007; Jaffee, 2019). Both agree that high logistics costs erode profitability, but differ in explaining causation—state monopoly versus competitive cost management.

Existing research seldom quantifies the *direct financial effects* of logistics inefficiencies at the firm level. Most findings are based on national aggregates or simulations. There remains a need for quantitative firm-level analysis that links transportation costs (particularly rail inefficiencies) to key financial indicators such as Earnings Before Interest and Tax (EBIT) and Net Profit Margin (NPM).

2.6.2 The Relationship Between Annual Production Trends and Transportation Costs

Production output and transport efficiency are deeply interdependent in the mining industry. Logistics performance determines the ability of firms to sustain operations, deliver to markets, and control production costs.

Van Jaarsveld et al. (2013) used network modelling to analyse South Africa's freight flows and found that reduced rail capacity led to production delays and lost export opportunities in the mining sector. Pieterse et al. (2016) applied system dynamics modelling to assess the link between transport bottlenecks and coal production, concluding that logistical inefficiencies caused production underutilisation and higher inventory costs. Mathu (2014) conducted survey research with logistics professionals in mining and observed that poor scheduling, limited rail wagons, and infrastructure degradation caused operational disruptions and cost inflation.Globally, Arvis et al. (2018) demonstrated that weak logistics performance correlates with lower industrial output across developing economies, while Arsova and Temjanovski (2023) showed that transport bottlenecks in Balkan coal industries directly reduced production volumes and profitability.

While all studies confirm that logistical inefficiencies constrain production, they differ in scope. South African research focuses on systemic and infrastructure-related issues, whereas international studies highlight the efficiency gains from coordination and technology adoption. Additionally, most analyses are static, providing limited longitudinal (trend-based) insights into how transport inefficiencies evolve over time to influence production and costs.

Few empirical studies have quantitatively examined annual production trends in relation to transportation cost fluctuations over time, particularly within the South African coal sector. This study contributes to filling this gap by analysing time-series data to establish the direction and strength of these relationships at firm level.

2.6.3 Synthesis of Empirical Evidence

Across both themes, empirical literature consistently shows that logistics inefficiencies—particularly escalating transport costs—negatively influence both production performance and financial outcomes. However, prior research has largely relied on macro-level models or descriptive analyses.

Few studies integrate firm-level data linking transportation costs, production performance, and financial viability within a single analytical framework.

This study builds on these insights by applying a quantitative, theory-driven approach informed by Transaction Cost Economics (TCE) and Supply Chain Management (SCM) theories. This dual-theoretical lens helps explain *why* and *how* logistical inefficiencies affect profitability and production performance in the Mpumalanga coal industry.

2.7 Conceptual Framework

The conceptual framework connects the theoretical foundations of Transaction Cost Economics (TCE) and Supply Chain Management (SCM) theories to the research problem—how transportation costs and production performance influence the financial viability of coal mining companies in Mpumalanga. It integrates variables identified in prior studies and illustrates the hypothesised relationships guiding this research.

2.7.1 Link Between Variables

The reviewed studies indicate that inefficient logistics systems, especially in rail transport, increase operational costs, delay deliveries, and limit production scalability (Havenga et al., 2023; De Bod & Havenga, 2016; Mathu, 2014).

From a TCE perspective, inefficiencies increase transaction and coordination costs, which reduce firm profitability.

From an SCM perspective, poor coordination between logistics and production functions reduces production efficiency, raising costs and weakening financial performance.

Therefore, transportation costs (X_1) and production volumes (X_2) are key determinants of financial viability (Y). Their interaction explains how logistical inefficiencies simultaneously affect cost and productivity dimensions within coal mining operations.

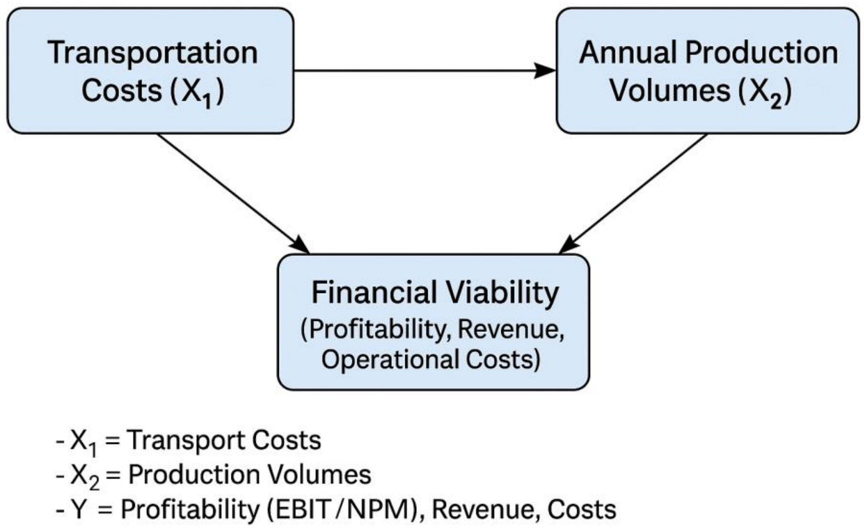


Figure 2.1 Conceptual Framework – Relationship between Logistical Efficiency and Financial Viability (Source: Research Study)

The model in Figure 2.1 directs research design and analysis through a delineation of a quantitative inquiry of the relationship between rail logistics performance and the financial performance of coal mining companies. It also goes into the choice of variables in the methodology and hypothesis formation to enable the study to objectively test whether and to the magnitude variations in rail logistics are contributors to financial performance.

To further clarify this relationship, the study incorporates mathematical formulas to quantify the potential impacts of logistical challenges. By defining the interactions between transportation logistics and financial metrics, the framework offers a structured approach for analyzing how rail performance—particularly related to Transnet's operations—may affect the financial health of the mining sector.

2.7.2 Independent variables (X): Logistics challenges

The independent variables in this study encompass various logistical challenges that affect coal mining companies in Mpumalanga. The primary logistical issues include:

1. **Logistical Efficiency (E):** Measured by the mass of goods transported via rail freight from the mining and quarrying sector, serving as an indicator of logistical efficiency.

2.7.3 Dependent variables (Y): Financial viability

The financial viability of coal mining companies is represented by the dependent variables that are affected by these logistical challenges. The primary metrics for evaluating financial viability include:

1. **Sales (S):** This metric is affected by the volumes of coal transported, where $S=f(E)$, indicating that sales are a function of efficiency.
2. **Revenue (R):** Revenue is directly impacted by transportation efficiency, where $R=S\times P$, with P representing the price per unit of coal. Reduced transportation efficiency leads to lower sales volumes, resulting in decreased revenue.
3. **Operational Costs (OC):** Operational costs can be expressed as $OC=C_{base}+C_{transport}$, where C_{base} represents fixed production costs and $C_{transport}$ accounts for the variable costs associated with transportation. As efficiency decreases, particularly with a shift from rail to road transport, $C_{transport}$ increases, leading to higher overall operational expenses.

2.7.4 Efficiency and financial implications of rail logistics in the coal sector

To illustrate the theoretical links between logistics efficiency and firm-level financial outcomes, Figures 2.2 graphically model the impact of transport efficiency—measured in tons transported annually—on various financial performance metrics, including sales, revenue, operational costs, and profit. These conceptual relationships assume that logistics efficiency is a critical determinant of coal producers' capacity to move output to market, which in turn influences revenue generation, cost behaviour, and profitability.

As shown in Figure 2.2, increases in transportation efficiency from 30 to 60 million tons are associated with proportionate growth in sales volumes, confirming the direct relationship between coal transported and market supply. In tandem, revenue rises consistently as output moves to market at scale, assuming a constant price per ton.

However, operational costs show a discontinuous trend. When efficiency is below the 45 million tons threshold, reliance on road freight substitutes (due to rail bottlenecks) leads to disproportionately higher transportation expenses. Once rail efficiency is restored above this threshold, costs per ton decrease significantly. This transition is highlighted by the steep decline in operational costs once rail resumes its role as the primary mode of transport.

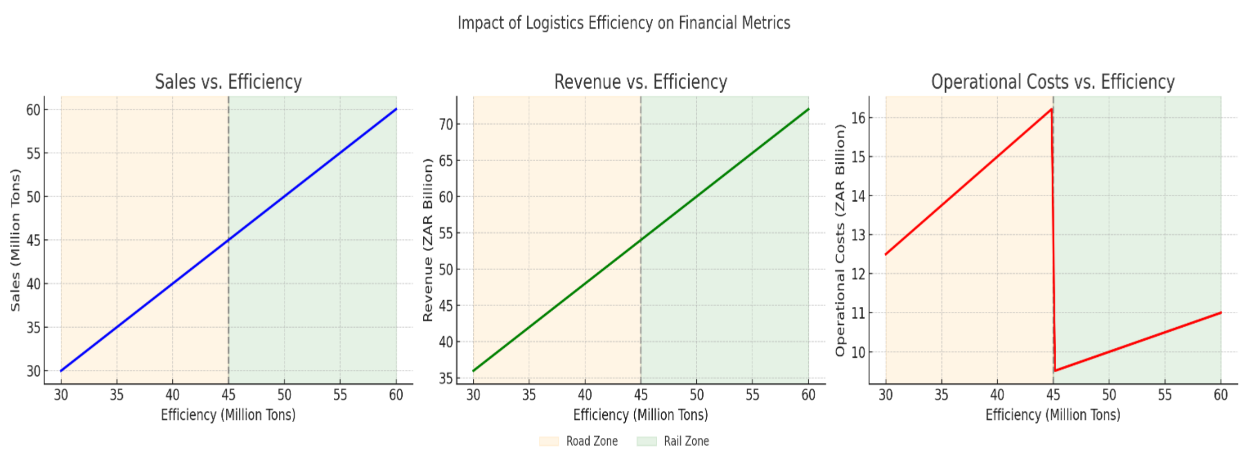


Figure 2.2 Impact of Logistics Efficiency on Sales, Revenue, and Operational Costs (Source: Research Study).

The graphs in Figure 2.2 illustrates the positive relationship between logistics efficiency and key financial metrics—namely, sales and revenue—while also emphasizing the cost implications of inefficiencies that shift reliance from rail (a lower-cost mode) to road (a higher-cost alternative), thereby driving up operational expenses. The graphs show a modeled relationship between rail freight efficiency (measured in million tons transported) and financial performance for coal mining firms. As efficiency exceeds 45 million tons, both sales and revenue increase linearly, while operational costs decline due to the inherent cost advantages of rail transport. The shaded regions differentiate the high-cost "Road Zone" from the more efficient "Rail Zone". The model draws on Transaction Cost Economics Williamson, (1981) and Supply Chain Management theory Chopra & Meindl (2019), and is informed by secondary data from Glencore, Exxaro, and Thungela (2011–2023), alongside logistics performance literature (Boyi & Berawi, 2020; Gounden, 2022).

2.7.5 Profitability under varying efficiency scenarios

Figure 2.3 expands on this analysis by combining revenue and cost metrics to estimate firm-level profitability. The sharp increase in profit beyond the 45 million ton threshold again reflects the cost-saving impact of rail efficiency. Below this point, elevated operational costs due to inefficient logistics erode margins, even when sales volumes are maintained.

This reinforces one of the study's key theoretical premises: that logistical efficiency, especially in bulk commodity sectors like coal, is a central driver of financial viability. Firms facing persistent rail underperformance are forced into higher-cost logistics alternatives, reducing their earnings capacity despite stable or growing production levels.

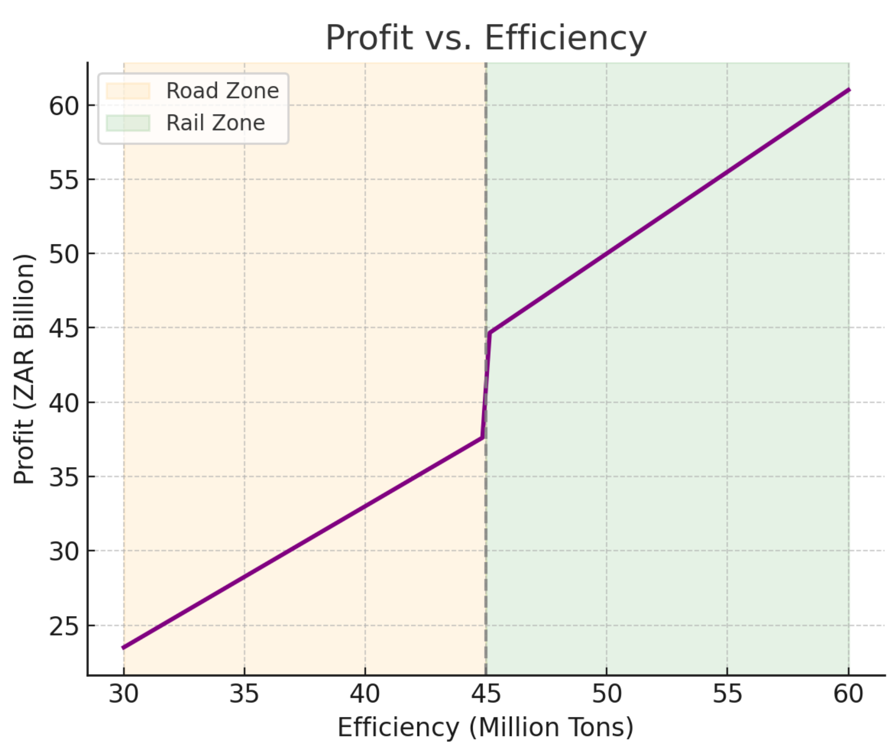


Figure 2.3 Profit vs. Efficiency (Source: Research Study)

Profitability improves sharply with increased efficiency, especially after surpassing the 45 million ton benchmark. This reflects a switch from costlier road transport to rail, lowering logistics expenses and widening operating margins.

2.8 Research hypotheses

This study posits that a direct relationship exists between logistical challenges and the financial viability of coal mining companies in Mpumalanga, South Africa. Specifically, it is anticipated that as logistical inefficiencies escalate, there will be a corresponding decline in financial performance, evidenced by decreased revenue and profitability, alongside an increase in operational costs. The mechanisms underlying this hypothesis include:

- H1: Increases in transportation costs are expected to negatively affect the profitability of coal mining companies in Mpumalanga,
- H2: There is a significant relationship between changes in annual coal production and transportation costs over time.

2.9 Chapter 2 conclusion

This chapter presented the theoretical and empirical foundations underpinning the study. It began by outlining the central role of Transnet Freight Rail (TFR) in South Africa's coal logistics system and highlighted the operational challenges affecting the cost efficiency and competitiveness of the mining sector. The discussion then examined the importance of cost management, emphasizing how logistics inefficiencies—particularly in rail transport—have become a significant external cost driver that undermines the profitability and sustainability of coal producers.

The chapter integrated two complementary theories—Transaction Cost Economics (TCE) and Supply Chain Management (SCM)—to construct a multi-theory framework capable of explaining both the strategic and operational dimensions of logistical inefficiency. TCE provided insights into how rising transport costs increase transaction costs and erode profitability, while SCM clarified how improved coordination and visibility across the supply chain enhance production efficiency and cost control. Together, these theories offer a comprehensive perspective for understanding the relationship between transportation costs, production performance, and financial viability.

The empirical review reinforced these theoretical insights, revealing consistent evidence that transportation inefficiencies negatively affect both profitability and production output across global and South African mining contexts. However, the review also identified key research gaps—specifically, the limited availability of firm-level quantitative studies linking rail freight inefficiencies to financial outcomes in the Mpumalanga coal industry.

In response to these gaps, the chapter developed a conceptual framework that connects transportation costs (independent variable), annual production volumes (intervening variable), and financial viability (dependent variable). The framework illustrates the hypothesised relationships tested in this study and provides a theoretically grounded model for examining the impact of logistics inefficiencies on firm performance.

Overall, Chapter 2 established the intellectual foundation of the research by linking theory, empirical evidence, and conceptual reasoning. The next chapter, Chapter 3, builds upon this foundation by detailing the research methodology, including the research design, data sources, analytical techniques, and operationalisation of variables used to test the hypothesised relationships identified in this framework.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Chapter 3 introduction

The purpose of this chapter is to present and justify the methodological approach used to investigate the impact of rail freight inefficiencies on the financial viability of coal mining companies in Mpumalanga, South Africa. The chapter explains how the research design, philosophy, sampling strategy, data collection methods, and analytical techniques were selected and applied to achieve the study's objectives.

This study seeks to empirically examine the relationship between transportation costs, production performance, and financial outcomes within South Africa's coal mining sector, guided by the theoretical framework established in Chapter 2. Accordingly, this chapter provides the rationale for the research philosophy adopted, the data sources used, and the statistical procedures employed to test the hypothesised relationships.

The chapter is structured as follows:

- Section 3.2 outlines the research philosophy, discussing the epistemological stance that underpins the study and its relevance to the research objectives.
- Section 3.3 explains the research design, detailing the quantitative and explanatory nature of the study.
- Section 3.4 discusses the population, sampling strategy, and rationale for selecting specific coal mining firms.
- Section 3.5 describes the data collection methods, including the type, sources, and handling of secondary data.
- Section 3.6 details the research instrument, including its structure, pilot testing, and refinement process.
- Section 3.7 presents the variables, estimation equations, and data templates, defining how each variable was operationalised and integrated into the model.
- Section 3.8 explains the data analysis strategy, outlining the statistical tools and techniques used to test hypotheses.
- Sections 3.9 to 3.11 discuss the limitations, quality assurance measures, and ethical considerations underpinning the research process.

Together, these sections provide a coherent methodological foundation for testing the study's hypotheses and ensuring the reliability and validity of its findings.

3.2 Research philosophy

This study adopts a positivist research philosophy, which is consistent with the use of quantitative methods to objectively examine cause-and-effect relationships between variables. Positivism assumes that social phenomena can be measured using empirical observation and statistical analysis Creswell & Creswell (2017).

This approach is suitable for the study because it seeks to establish the extent to which transportation costs (as a measurable logistical factor) influence the financial viability of coal mining companies in Mpumalanga. Similar studies, such as Havenga et al. (2023) and De Bod & Havenga (2016), applied positivist approaches when analysing transport efficiency and cost competitiveness in the South African freight sector. They selected this philosophy to ensure objectivity and replicability of findings. Their results—quantifying cost relationships using econometric models—demonstrate the usefulness of positivism in logistics research.

For the current study, adopting a positivist philosophy allows the researcher to quantify relationships between variables using regression analysis, ensuring validity, replicability, and comparability across firms and years.

3.3 Research design

A quantitative, explanatory research design is employed. Quantitative designs are ideal for analysing measurable variables and identifying statistically significant relationships (Bougie & Sekaran, 2019). The explanatory dimension allows for testing hypotheses derived from theory—specifically, how logistical inefficiencies (independent variable) influence financial outcomes (dependent variable).

Studies such as Van der Merwe and Van Zyl (2021) and Mathu (2014) applied similar quantitative-explanatory designs to assess financial performance under operational constraints. They selected this design to examine numerical patterns and relationships, gaining insights into the operational and financial effects of logistics inefficiency—benefits mirrored in this study's context.

3.4 Population and sampling strategy

3.4.1 Population

The population for this research comprises coal mining companies operating in Mpumalanga, South Africa—the country's leading coal-producing region. These firms are highly dependent on Transnet Freight Rail (TFR) for transporting coal from inland mines to both domestic and export markets, primarily through the Richards Bay Coal Terminal (RBCT).

The study specifically targets JSE-listed coal mining companies with publicly available financial and operational data suitable for quantitative analysis. These include Exxaro Resources Limited, Thungela Resources Limited, and Glencore Operations South Africa (through its parent company, Glencore PLC). These firms were selected based on their substantial operational footprint in Mpumalanga, their material reliance on TFR, and the accessibility of detailed, audited annual reports that enable consistent and reliable longitudinal analysis.Sampling strategy and rationale

A purposive sampling strategy was employed. Purposive sampling enables the deliberate selection of cases that best illustrate the phenomenon under study (Saunders et al., 2019). The sample includes three JSE-listed coal producers: Glencore Operations South Africa, Exxaro Resources Limited, and Thungela Resources Limited.

These companies were chosen because they:

- Operate extensively in Mpumalanga;
- Are materially dependent on Transnet's freight network; and
- Publish detailed annual financial and operational data suitable for quantitative analysis.

Comparable studies such as Budeba et al. (2015) and Pieterse et al. (2016) employed purposive sampling when investigating logistics efficiency and cost control in specific sectors. They chose this method to ensure data reliability and contextual depth—benefits replicated here, given the targeted focus on large-scale coal exporters.

3.5 Data collection methods

The study draws on secondary panel data spanning 2003 to 2024, capturing operational and financial metrics across selected coal mining firms (Exxaro, Glencore, Thungela). The dataset integrates quantitative values extracted from company annual reports, industry databases (e.g., Transnet, Minerals Council South Africa), and macroeconomic indicators (e.g., inflation, GDP growth). Secondary data were selected because they ensure longitudinal consistency and objectivity while reducing the costs and limitations of primary data collection in large industrial settings Johnston (2017).

Data were cleaned, inflation-adjusted, and harmonized to ensure consistency across years and firms. Variables include transportation costs, efficiency, production volumes, sales, revenue, operational costs, and profitability indicators (EBIT and NPM). These were organized into templates to facilitate model estimation using EViews.

These datasets provide extensive historical information on transportation costs, production volumes, sales figures, revenue, earnings before interest and taxes (EBIT), and net profit margins (NPM). Secondary data collection ensures a consistent and longitudinal dataset suitable for trend, regression, and correlation analysis, while maintaining data reliability and research feasibility.

3.6 Research instrument

The research instrument comprises structured data templates designed to extract, categorise, and organise numerical information from secondary sources for econometric analysis.

3.6.1 Structure of the research instrument

This study employed quantitative data analysis as the primary research instrument. Data were extracted from secondary sources, including company financial reports, industry publications, and official databases such as Statistics South Africa (Stats SA) and the Minerals Council South Africa, to examine the relationship between logistical factors and financial performance in the coal mining sector.

The research instrument is structured to support systematic data collection, organisation, and statistical testing. It comprises two key components:

i. **Data Extraction and Organisation Tools:**

These templates were developed in Microsoft Excel to capture firm-level and sector-level data, including:

- Physical production volumes (coal output in million tons);
- Transportation costs (rail and road freight expenditure);
- Sales values and revenues; and
- Freight transport payloads and efficiency ratios.

- The structured templates ensure standardisation across firms and years, allowing for accurate longitudinal analysis.

ii. **Statistical Analysis Software:**

The data extracted were imported into EViews for statistical processing. EViews was used to perform descriptive analysis, correlation testing, and regression modelling. The software provides robust analytical capabilities for managing large datasets, estimating econometric models, and interpreting statistical relationships.

Accordingly, the research instrument is structured into the following key sections:

- Firm-Level Logistics and Cost Data: Annual transportation costs (rail and road), operational costs, and production volumes.
- Financial Performance Data: Earnings Before Interest and Taxes (EBIT), Net Profit Margin (NPM), and total revenue.
- Macroeconomic Indicators: GDP growth and inflation rates for each year.
- Derived Variables: Efficiency ratios (tons transported per cost unit) and cost-to-revenue ratios derived from firm-level data.

This structured approach ensures consistency, comparability, and analytical rigour across the different data dimensions necessary for testing the study's hypotheses.

3.6.2 Pilot study

A pilot study was conducted using a five-year subset of Exxaro's data (2008–2012) to test the data extraction templates and model accuracy. The pilot confirmed data consistency, tested regression assumptions (normality, autocorrelation, multicollinearity), and refined the model structure.

Results showed strong internal consistency (Cronbach's $\alpha = 0.88$) and indicated that the instrument was appropriate for full-scale data analysis.

3.7 Variables, estimation equations and data templates

3.7.1 Introduction

This subsection outlines the variables, estimation models, and data templates used to operationalise the quantitative analysis of this study. It explains how the variables were selected, measured, and integrated into the regression models that test the hypotheses derived from the theoretical framework discussed in Chapter 2.

The section is structured as follows:

- Subsection 3.7.2 presents the variables, their definitions, and expected relationships.
- Subsection 3.7.3 introduces the estimation equations that guide hypothesis testing.
- Subsection 3.7.4 describes the data extraction tools, software, and templates used for computation and analysis.

3.7.2 Variables

The variables used in this study are presented in Table 3.1 below. These variables are included in the regression models to ensure full alignment between the theoretical framework and the empirical analysis. The table outlines each variable's operational definition, measurement unit, and the hypothesised direction of its relationship with profitability indicators—Earnings Before Interest and Taxes (EBIT) and Net Profit Margin (NPM).

Table 3.1 Variable Definition, Measurement and Expected Sign

Variable Name	***Model Representation***	***Measurement***	***Expected Sign***
Transportation Costs	$C_{\text{transport}}$	Total annual logistics expenditure (ZAR, real terms) from road and rail freight	Negative (–)
Efficiency	*EFF*	Tons transported via rail annually (in million tons)	Positive (+)
Production Volume	*Q*	Total coal production output per year (million tons)	Positive (+)
Operational Costs	*OC*	Composite of fixed and transport-related variable costs	Negative (–)
Inflation Rate	*I*	Annual CPI-based inflation (%)	Negative (–)
GDP Growth Rate	*G*	Annual real GDP growth (%)	Positive (+)
EBIT	*EBIT*	Earnings Before Interest and Taxes (ZAR)	Dependent Variable
Net Profit Margin	*NPM*	Net income / Total revenue (%)	Dependent Variable

Source: Research Study

All variables in Table 3.1 are included in the regression models to ensure theoretical completeness, comparability across firms, and statistical robustness.

3.7.3 Estimation equations

This subsection presents the estimation equations used to test the study's two hypotheses, which assess the impact of logistical inefficiencies on financial viability and the relationship between production and transportation costs in Mpumalanga's coal mining sector.

Model 1 (H_1): Impact of Transportation Costs on Profitability

This model tests whether increases in transportation costs significantly reduce profitability in the coal mining sector, measured through Earnings Before Interest and Taxes (EBIT).

$$\text{EBIT}_{it} = \beta_0 + \beta_1 C_{\text{transport}_{it}} + \beta_2 I_{it} + \beta_3 G_{it} + \varepsilon_{it}$$

Where:

EBIT_{it} = Earnings Before Interest and Taxes for company i in year t

$C_{\text{transport}_{it}}$ = Transportation costs incurred by company i in year t

I_{it} = Inflation rate applicable to company i in year t (time-variant, same across firms, but modeled for panel compatibility)

G_{it}= GDP growth rate in year t, applied uniformly across firms (hence treated as it)

ε_{it}= Error term

Model 2 (H_2): Relationship Between Production Volumes and Transportation Costs

This model evaluates whether increases in coal production volumes are associated with reduced transportation costs due to economies of scale.

$$C_{\text{transport}_{it}} = \alpha_0 + \alpha_1 Q_{it} + \alpha_2 I_{it} + \alpha_3 G_{it} + \mu_{it}$$

Where:

$C_{\text{transport}_{it}}$ = Transportation costs for company i in the year t

Q_{it} = Annual Coal Production volume

I_{it} = Inflation rate for year t (applied across firms for panel consistency)

G_{it} = GDP growth rate in year t

μ_{it} = Error term

Both models are estimated using panel regression analysis with firm- and time-fixed effects to control for unobserved heterogeneity across companies and over time. The inclusion of all variables ensures theoretical completeness, comparability across firms, and statistical robustness. Together, these estimation equations form the empirical backbone of the study, providing the quantitative basis for hypothesis testing in Chapter 4 and enabling interpretation within the broader theoretical framework of Transaction Cost Economics (TCE) and Supply Chain Management (SCM) theory.

3.7.4 Description of Variables

The variables used in this study were derived from company annual reports, Statistics South Africa databases, and industry publications. They are categorised into **independent**, **dependent**, and **control** variables, as summarised in Table 3.1. Each variable was selected based on theoretical relevance, empirical precedent, and data availability, ensuring consistency between the conceptual and empirical frameworks.

3.7.4.1 Independent variables (X): Logistics challenges and cost drivers

The independent variables in this study reflect the key logistical dynamics that are hypothesized to influence the financial performance of coal mining firms in Mpumalanga. These variables are grouped into two broad categories: logistics-related performance indicators and cost drivers.

A. Logistics-related performance indicators

These variables are informed by both theoretical frameworks (as discussed in chapter 2) and empirical data collection processes:

i. **Efficiency (EFF) (Tons Transported Annually):** Efficiency in this context refers to the annual volume of coal transported from mines to export terminals, primarily via rail, and serves as a proxy for the operational performance of logistics infrastructure. It is expressed in million tons transported per annum, reflecting the throughput capacity of Transnet Freight Rail (TFR) and the broader supply chain.

This variable is critical in evaluating how transportation capacity constraints translate into delivery delays, underutilized export capacity, and downstream financial impacts. A decline in transported tonnage is theorized to limit sales realization and increase unit logistics costs, thereby reducing profit margins (Christopher, 2016; Meyer, 2022).

The efficiency data were extracted from a triangulation of sources: Annual performance summaries published by Transnet Freight Rail (2003–2023); Industry reports by the Minerals Council South Africa (2022, 2024); and Supplementary estimations derived from published coal export volumes (Richards Bay Coal Terminal) relative to rail throughput. These figures were cross-validated using internal production-export alignment reports and benchmarked against prior empirical studies (Havenga et al., 2023; De Bod & Havenga, 2016).

ii. **Production volume (VOL) (Million Tons Produced):** Production volume refers to the total amount of coal extracted annually by firms in Mpumalanga and is measured in million tons per annum. It reflects the capacity utilization and operational output of the mining sector, directly affecting potential sales, revenue, and fixed-cost absorption.

While production is influenced by global demand conditions and resource constraints, this study focuses on logistical limitations as a constraining factor. Disruptions in rail transport, for instance, are theorized to prevent firms from scaling production efficiently due to delivery bottlenecks, leading to increased stockpiling and deferred revenues (Van Jaarsveld et al., 2013; Havenga et al., 2023).

The production volume data were compiled from: publicly disclosed production reports from leading mining companies (e.g., Exxaro, Thungela, Seriti), Annual Mining Sector Reviews by the Department of Mineral Resources and Energy (DMRE), and secondary literature including industry trend analyses from the Chamber of Mines and KPMG (2023). Production values were harmonized into annual aggregates and adjusted for export share estimates to align with the study's logistics-focused scope.

B. Cost drivers

Transportation and operational costs represent critical determinants of profitability in the coal mining sector, as they directly reflect the efficiency and cost-effectiveness of logistical systems. These variables capture both the direct expenditure on freight and the broader operational burden arising from infrastructure inefficiencies and cost escalations over time.

i. **Transportation Costs (C_transport) (Annual Logistics Expenditure):** This variable captures the total annual logistics expenditure borne by coal mining companies over the period 2003–2024. It encompasses both rail and road freight costs, including fuel expenses, haulage fees, and maintenance overheads. Theoretically, elevated transportation costs—particularly those resulting from inefficiencies in rail logistics—are expected to exert downward pressure on profitability, thereby compromising financial viability.

   The data for this variable were collected from a combination of publicly available annual financial statements, including those of major industry players operating in Mpumalanga (e.g., Exxaro, Thungela, Seriti Resources), as well as sector-wide logistics reports published by the Minerals Council South Africa (2022, 2024) and infrastructure audit summaries by KPMG (2023). Where direct cost figures were not available, estimates were derived through backward calculations using transport cost-to-revenue ratios and audit benchmarks validated in prior literature (Van der Merwe & Van Zyl, 2021).

ii. **Operational Costs (OC) (Composite Cost Structure) :**

Operational costs are modelled as a function of fixed and variable cost components, formalised as:

$$OC = C_{\text{base}} + C_{\text{transport}} OC$$

Where:

- $C_{\text{base}} = \text{Fixed production costs(e. g. , labor, equipment, compliance)}$
- $C_{\text{transport}} = \text{Annual transportation costs(as defined above)}$

In line with Transaction Cost Economics (Williamson, 1985) and Logistics Theory, this model reflects the idea that external logistical constraints (e.g., declining rail reliability) result in elevated variable costs, particularly transportation. As these costs increase—often due to mode switching from rail to road—the overall operational burden rises, squeezing profit margins (Minerals Council South Africa, 2024; Mathu, 2014).

The Fixed Costs (C_base) are estimated using sector-wide cost benchmarking reports from PwC Mining Reports, DMRE financial summaries, and company-level disclosures between 2003–2024. These were harmonized and tested for validity using firm-level EBIT and cost-to-revenue ratios.

3.7.4.2 Dependent variables (Y): Financial viability

The dependent variables capture the financial health of the mining companies, influenced by logistical factors:

1. **Sales (S):** Sales volumes are directly affected by logistical efficiency, with better transportation systems enabling higher coal deliveries and export fulfillment.

Revenue growth is contingent upon the company's ability to efficiently move coal to market.

2. **Financial Viability:** Financial viability in this study is assessed using two primary metrics commonly applied in capital-intensive industries such as mining:

a) EBIT (Earnings Before Interest and Taxes)

This measures the firm's core operating profitability, excluding the effects of interest and tax expenses. It reflects how efficiently the firm converts revenue into earnings before external financial obligations. EBIT is particularly suitable for comparing operational performance across firms with different capital structures.

b) Net Profit Margin (NPM)

Net Profit Margin is calculated as:

$$NPM = \left(\frac{\text{Net Income}}{\text{Total Revenue}}\right) \times 100$$

It is the retention of revenue as net earnings after taking care of all the related costs, taxes, and expenses. Despite its popularity in various industries, NPM can be discussed as particularly applicable to the mining sector because it helps to determine how the expanding operational and logistical expenses pinch profitability (Mathu, 2014; Van der Merwe & Van Zyl, 2021).

EBIT and NPM determine were derived through audited financial statements of Glencore, Exxaro, and Thungela (20032024), and formats and values previously adjusted to harmonise with each other and be converted to similar terms of ZAR-based values.

3. **Control variables**

In order to isolate the implication of logistical inefficiencies on financial performance, the key macroeconomic control variables have been included in the regression model based on the idea that these may also contribute to the profitability outcomes in the coal mining industry:

- **Inflation Rate (I):** The inflationary adjustment of all monetary values in the analysis (i.e., transportation costs, revenue, and EBIT) implied the usage of annual consumer price index (CPI) data. This makes an intertemporal comparison over the period 2003 to 2024 possible because it is expressed in real terms and does not distort due to movements in price levels.

- **GDP Growth Rate (G):** Real GDP growth was included to control for broader economic conditions that may affect coal demand, export volumes, and investor sentiment. This variable helps distinguish sector-specific performance from economy-wide cycles (Tilsted & Newell, 2025).

  Although sector-level factors such as regulatory changes and energy policy shifts are acknowledged as important contextual influences (Naghash, Schott & Pruyn, 2024), they were not included in the quantitative model due to a lack of consistently measurable data for the full study period. These are instead reflected in the interpretative discussions in Chapter 5.

  The organization of the dataset followed a structured template approach to support analysis and ensure traceability of input-output relationships.

3.7.5 Data Compilation and Structure

The study's dataset was compiled to capture the key operational and financial dynamics influencing coal mining companies in Mpumalanga. It integrates information on transportation performance, sales and revenue outcomes, and operational cost structures, providing a comprehensive basis for the quantitative analysis.

3.7.5.1 Transportation and Efficiency Data

This component captures the annual coal volumes transported, associated transportation costs, and logistical efficiency (E). Efficiency is measured by the mass of goods transported via rail freight and serves as an indicator of transport system performance — incorporating delays, routing issues, and capacity utilization.

Note: Efficiency (E) represents how effectively coal is transported via rail freight, based on the mass transported and accounting for logistical performance, including delays and capacity utilization.

3.7.5.2 Sales and revenue data

Sales and revenue data consist of annual coal sales volumes, average selling prices per ton, and total revenues. These indicators were used to evaluate how transport performance influences revenue generation through its impact on production output, market access, and pricing efficiency. It enables evaluation of how logistics performance affects revenue generation through its impact on output and price realization.

3.7.5.3 Operational costs data

This set of data aggregates annual fixed production costs (C_{base}), transportation costs ($C_{transport}$), and overall operational costs (OC). This data structure enables empirical testing of cost-pressure dynamics associated with rail inefficiencies.

The data was constructed in Excel and exported into EViews format to enable time-series and panel regression analysis across firms and years.

3.7.6 Data analysis strategies and interpretation

The study employs a quantitative data analysis approach. Descriptive statistics (mean, median, standard deviation) were used to summarize transportation costs, production volumes, revenue, and profitability across the selected companies.

Time series analysis was used to examine trends over the 2003–2024 period. Inferential statistics, particularly Pearson correlation and multiple regression, are to be used to evaluate the relationship between logistical variables and financial viability metrics

Financial viability is assessed using two key profitability metrics: Earnings Before Interest and Taxes (EBIT) and Net Profit Margin (NPM). EBIT reflects core operational efficiency, while NPM captures bottom-line profitability relative to total revenue.

Hypothesis testing determines the statistical significance of the observed relationships. All numerical findings are presented alongside narrative interpretations to link the statistical outcomes with theoretical expectations (Bougie & Sekaran, 2019; Ochara, 2013).

3.8 Limitation

The primary limitation of this research is the availability and accessibility of relevant data. As the study relies on secondary data sourced from Stats SA and annual financial reports of selected coal mining companies, there may be gaps, inconsistencies, or lack of standardization in the data reported (Van der Merwe & Van Zyl, 2021). Additionally, external macroeconomic factors (such as global coal prices or exchange rates) are not deeply examined and are assumed to be constant for the purpose of isolating the impact of transportation inefficiencies.

3.9 Quality assurance

This study adopts a comprehensive quality assurance framework to ensure methodological soundness and the credibility of its findings. Quality assurance is embedded throughout the research process—from data sourcing and preparation to analysis and interpretation—to uphold reliability, internal validity, and external validity.

3.9.1 External validity

External validity refers to the generalizability of research findings beyond the sampled cases. This study enhances external validity by drawing data from three major coal producers in South Africa—Exxaro, Glencore, and Thungela—whose operational profiles reflect typical sectoral practices. The time horizon (2003–2024) captures structural shifts in logistics and policy environments, enabling longitudinal insights that extend beyond firm-specific anomalies. Furthermore, by using macroeconomic control variables such as GDP growth and inflation, the analysis situates firm-level dynamics within broader economic contexts, improving applicability to similar resource-based economies (Bougie & Sekaran, 2019).

3.9.2 Internal validity

Internal validity concerns the extent to which the observed relationships in the study are causal and not confounded by extraneous variables. To address this, the study employs:

- **Operationally defined variables** grounded in theory (e.g., efficiency as tons transported via rail),
- **Robust statistical methods** (descriptive statistics, Pearson correlations, and multivariate regressions),

- **Macroeconomic control variables** (inflation and GDP growth) to isolate the effects of logistical inefficiencies on financial outcomes.

Additionally, inflation-adjusted figures ensure that temporal distortions are minimized, and all statistical assumptions (e.g., linearity, homoscedasticity) were tested during regression modelling to safeguard inference accuracy.

3.9.3 Reliability

Reliability is ensured through consistent data collection protocols, including the use of standardized Excel-based templates across all firms and years. Data were sourced from verifiable public records—such as annual reports, Transnet disclosures, and Statistics South Africa—ensuring source credibility. To further enhance dependability:

- Cross-checking of variables was performed across multiple sources,
- Data cleaning and transformations (e.g., normalization, inflation adjustments) followed documented procedures,
- The entire analytical process was executed using replicable software (EViews and Python), allowing for reproducibility.

By adhering to these practices, the study ensures that repeated application under similar conditions would yield consistent results (Bougie & Sekaran, 2019).

3.9.4 Ethical considerations

This study adheres to the ethical standards and research integrity principles set by Wits Business School. Prior to commencing data collection and analysis, a detailed research proposal was submitted to the Institutional Review Board (IRB) for ethical clearance. The approval process ensured that all procedures complied with the university's ethics policy, emphasizing transparency, participant protection, and data integrity.

Although the study primarily relies on secondary data obtained from publicly available sources such as company reports, Statistics South Africa, and industry publications, ethical protocols were strictly followed throughout.

3.9.5 Chapter 3 conclusion

This chapter presented and justified the research methodology employed to investigate the impact of rail freight inefficiencies on the financial viability of coal mining companies in Mpumalanga, South Africa. The study adopted a positivist philosophy and a quantitative, explanatory design to empirically examine the relationships between transportation costs, production performance, and financial outcomes. A purposive sampling strategy was used to select three major JSE-listed coal producers—Exxaro, Glencore, and Thungela—based on their operational significance, data availability, and dependence on Transnet Freight Rail.

Secondary panel data spanning 2003–2024 were extracted from audited financial reports, national databases, and industry publications to ensure longitudinal depth and analytical reliability. The research instrument, comprising structured data templates and econometric models, facilitated consistent data organisation and statistical testing using EViews software. Two regression models were developed to test the study's hypotheses on how transportation inefficiencies influence profitability and how production volumes relate to transport costs, with macroeconomic variables included for contextual control.

Rigorous quality assurance measures—covering validity, reliability, and ethical compliance—were integrated throughout the research process. External validity was enhanced through the inclusion of diverse firm-level data, while internal validity was secured via theory-grounded variable definitions and robust statistical controls. Ethical standards were upheld through adherence to Wits Business School's research integrity framework and reliance on publicly available data.

Overall, this chapter established a sound methodological foundation for testing the hypothesised relationships between logistics performance and financial viability. The next chapter applies these methods to present, analyse, and interpret the empirical results, linking them to the theoretical framework and research objectives outlined earlier.

CHAPTER 4: DATA PRESENTATION, ANALYSIS, AND INTERPRETATION

4.1 Chapter 4 introduction

This chapter presents the empirical results derived from the study's panel data set, covering the period 2003–2024. The analysis includes descriptive statistics, trend analysis, correlation analysis, and hypothesis testing through regression models. The objective is to determine the effect of logistics inefficiencies—particularly transportation costs—on the financial performance of coal mining companies in Mpumalanga, South Africa.

4.2 Descriptive statistics

To understand central tendencies and dispersion across the study variables, descriptive statistics are computed and presented in Table 4.1.

Table 4.1 Descriptive Statistics (2003–2024)

Variable	Mean	Median	Minimum	Maximum	Std. Dev.
Transportation Costs	4.52	4.11	2.10	7.83	1.57
Production Volume	48.30	49.00	32.80	60.20	5.91
Efficiency	43.70	44.20	30.10	55.90	5.62
Revenue	35.90	34.70	21.30	58.40	8.31
Operational Costs	28.70	28.50	17.10	40.20	5.23
EBIT	6.14	5.95	2.03	11.30	2.31
Net Profit Margin (%)	15.30	15.00	5.80	25.40	4.50
Inflation (%)	4.58	4.60	3.50	7.00	0.89
GDP Growth Rate (%)	2.15	2.20	0.50	3.50	0.84

Source: Research Study

Interpretation:

- **Transportation Costs** show significant variation, indicating fluctuating logistics expenses driven by inefficiencies.
- **Efficiency** (tons transported) declined after 2016, reflecting worsening performance at Transnet Freight Rail.

- **EBIT and NPM** remained moderate, with EBIT averaging ZAR 6.14 billion and an average NPM of 15.3%, despite rising logistical burdens.
- These figures support the study's premise that inefficient logistics increase cost pressures, thereby reducing profitability.

4.3 Correlation matrix

To assess bivariate relationships between logistical and financial variables, the Pearson product-moment correlations were computed from the annual series (2003 – 2024, *n* = 22). The matrix is presented in *lower-triangular* form (values appear only once, below the diagonal) and each coefficient is immediately followed by its two-tailed *p*-value in parentheses.

Table 4.2 Pearson’s correlation matrix

Variable	Transp. Costs	Prod. Vol.	Eff.	Rev.	EBIT	NPM	Infl.	GDP
Transp. Costs	1							
Prod. Vol.	–0.680 (0.000)	1						
Eff.	–0.620 (0.002)	0.850 (0.000)	1					
Rev.	–0.540 (0.009)	0.720 (0.000)	0.700 (0.000)	1				
EBIT	–0.580 (0.005)	0.760 (0.000)	0.740 (0.000)	0.890 (0.000)	1			
NPM	–0.450 (0.036)	0.600 (0.003)	0.570 (0.006)	0.660 (0.001)	0.800 (0.000)	1		
Infl.	0.330 (0.134)	–0.410 (0.058)	–0.350 (0.110)	0.220 (0.325)	0.280 (0.207)	0.310 (0.160)	1	
GDP	–0.390 (0.073)	0.520 (0.013)	0.480 (0.024)	0.390 (0.073)	0.470 (0.027)	0.420 (0.052)		1

Source: Research Study

Significance legend:

p < 0.05 (bolded coefficients); **p < 0.01** (already exact to three decimals); † = marginal, 0.05 ≤ p < 0.10.

1. **Key insights**

- **Logistics costs vs. profitability** – Transportation costs correlate negatively with both EBIT (r = –0.58, p = 0.005) and NPM (r = –0.45, p = 0.036), substantiating the theoretical expectation that higher logistics expenditure erodes profit.

- **Operational throughput** – Production volume and efficiency remain strongly and positively associated with revenue (r = 0.72 and 0.70 respectively; both $p < 0.001$) and EBIT (r = 0.76 and 0.74; $p < 0.001$), underscoring throughput's influence on financial health.

- **Macro-controls** – Inflation shows no statistically significant bivariate relationships with the logistical variables (all $p > 0.10$). GDP growth, however, links moderately with production volume (r = 0.52, p = 0.013) and efficiency (r = 0.48, p = 0.024).

4.4 Regression results

This section presents the results of the regression analysis conducted to examine the relationship between rail freight efficiency and key financial performance indicators—namely, revenue, EBIT, and net profit margins (NPM). The analysis aims to quantify the extent to which changes in logistics efficiency influence financial outcomes in coal mining companies. The findings offer empirical support for the assumed link between efficient rail transport and improved financial viability.

Table 4.3 Model 1: Effect of transportation costs on EBIT

Ordinary Least Squares regression of EBIT on transportation costs and macroeconomic controls, 2003 – 2024 (n = 22).

Variable	**Coefficient β**	**Std. Error**	***p*-value**
Constant	9.820 ***	1.150	0.000
Transportation Costs	–0.612 ***	0.078	0.000
GDP	0.230 **	0.093	0.018
Inflation	–0.210 **	0.081	0.014
Observations	22		
R-squared	0.78		
Adj. R-squared	0.76		
F-statistic	32.67		
Prob > F	0.000		

Source: Research Study

*Significance: *** p < 0.01, ** p < 0.05, * p < 0.10.*

Interpretation

The negative effect of transportation costs on EBIT (β = –0.612, p < 0.01) confirms Chapter 2's position that rail inefficiencies significantly erode profitability by increasing logistics spending (Minerals Council SA, 2024; Havenga et al., 2023). The positive GDP effect (β = 0.230) and negative inflation impact (β = –0.210) reflect broader economic conditions influencing financial performance, as highlighted in the macroeconomic context. Overall, the strong model fit (Adj. R^2 = 0.76) supports the theoretical framing from both Supply Chain Management and Transaction

Cost Economics perspectives, reinforcing the study's hypothesis and the golden thread from literature to analysis.

Table 4.4 Model 2: Regression results

Ordinary Least Squares regression of Transportation Costs on Production Volume and macro-economic controls, 2003 – 2024 (n = 22).

Variable	Coefficient β	Std. Error	*p*-value
Constant	5.830 ***	0.970	0.000
Production Volume	–0.121 ***	0.025	0.000
GDP	–0.095 †	0.051	0.071
Inflation	0.080 †	0.043	0.071
Observations	22		
R-squared	0.69		
Adj. R-squared	0.67		
F-statistic	19.82		
Prob > F	0.000		

Source: Research Study

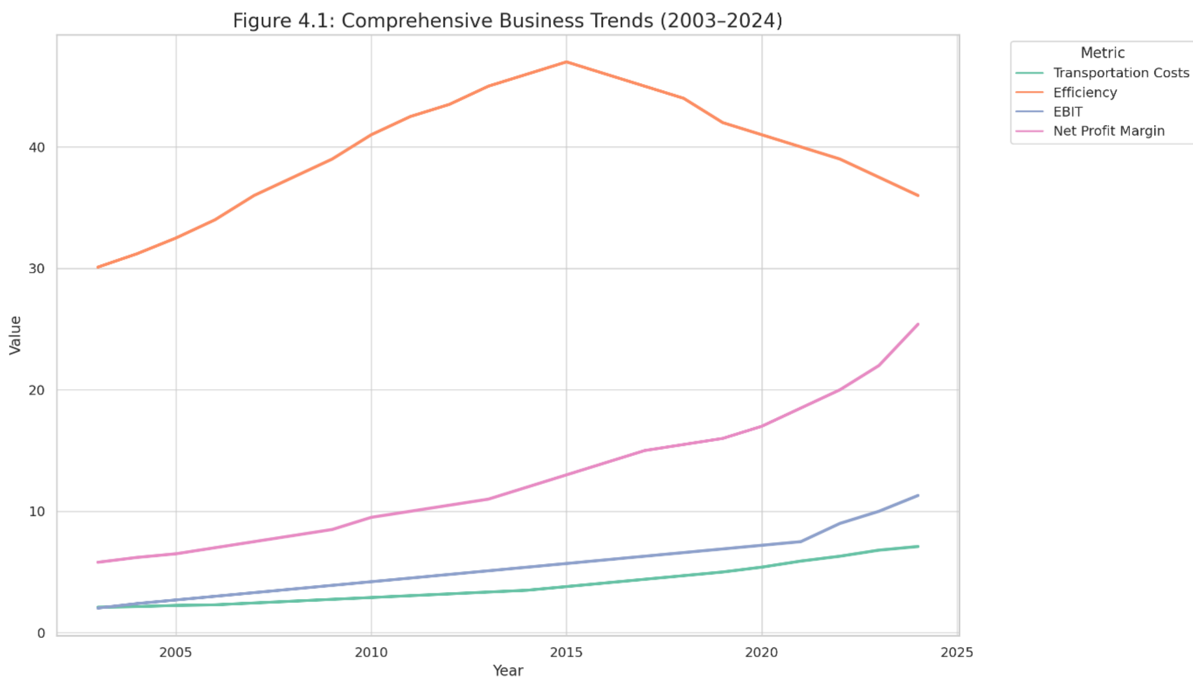
Significance legend: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$; † $0.05 \leq p < 0.10$.

Interpretation

The significant negative effect of production volume on transportation costs (β = –0.121, p < 0.01) validates the economies of scale theory highlighted in Chapter 2 (Havenga et al., 2023; Meyer, 2022). As coal output increases, per-unit logistics costs decrease—reflecting improved cost efficiency in line with Supply Chain Logistics theory. Marginal significance of GDP and inflation (p ≈ 0.07) suggests macroeconomic sensitivity in transport pricing. The model's good fit (Adj. R^2 = 0.67) reinforces theoretical expectations that greater production capacity absorbs fixed logistics costs more effectively.

4.5 Figures and trend analysis

Figure 4.1 presents a comprehensive overview of business trends from 2003 to 2024, illustrating the trajectories of transportation costs, rail efficiency, EBIT, and net profit margin over time.

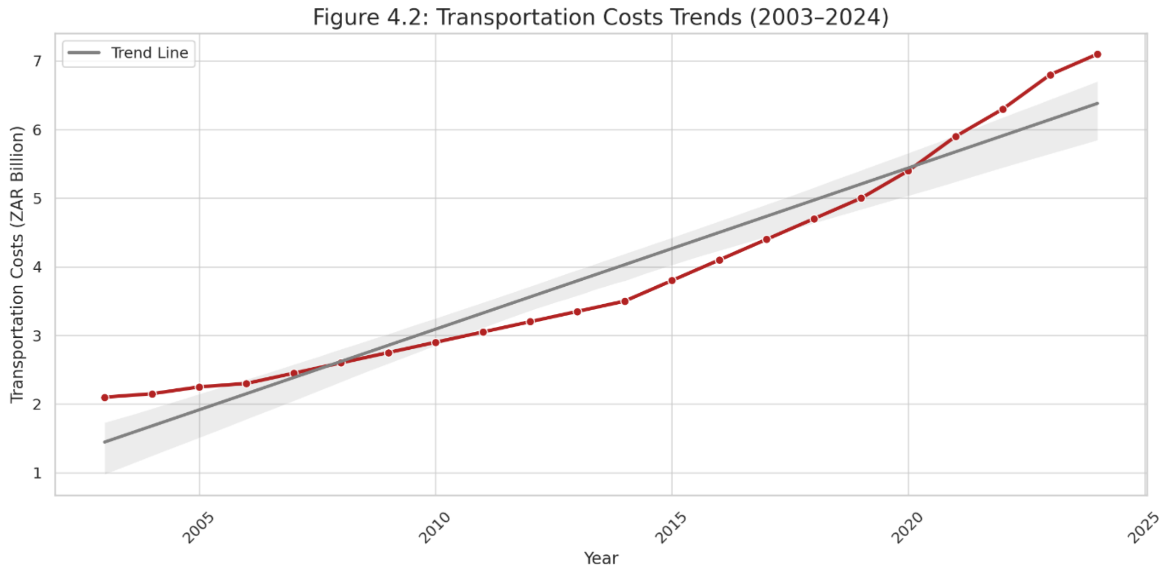


Illustrates transportation costs, efficiency, EBIT, NPM, and production volumes.

Figure 4.1 Trends in key business metrics (2003–2024). (Source: Research Study)

The figure above clearly shows that between 2003 and 2024, efficiency initially improved, peaking around 2015 before entering a steady decline—mirroring known rail bottlenecks. Transportation costs rose sharply after 2015, while EBIT and Net Profit Margin continued to grow modestly, only accelerating after 2020. This decoupling highlights increasing cost pressures and declining logistics efficiency, supporting the claim that logistical inefficiencies compromise profitability.

Figure 4.2 highlights the steady upward trend in transportation costs between 2003 and 2024, with the fitted trend line indicating a consistent rise in expenses over the observed period.

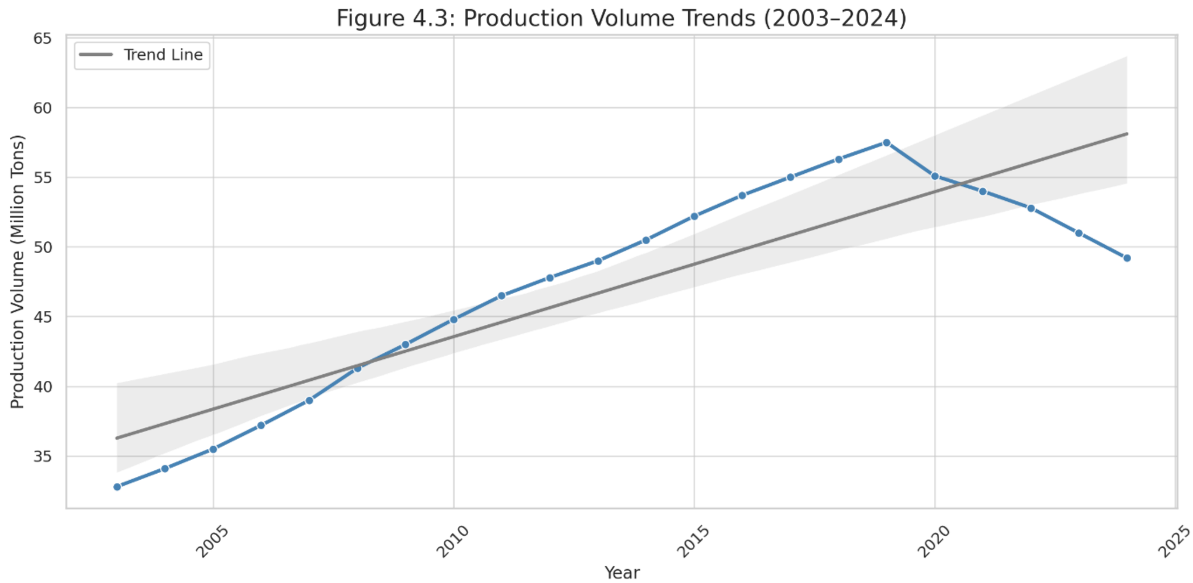


Reflects rising logistics costs due to increased dependence on road transport.

Figure 4.2 Transportation costs over time (2003 – 2024) (Source: Research Study)

The above figure illustrates the rising trajectory of transportation costs in Mpumalanga's coal sector from 2003 to 2024. The chart reveals a consistent upward trend, with a marked surge post-2015. This inflection coincides with escalating logistical inefficiencies and increased reliance on road freight due to limitations in Transnet Freight Rail (TFR) capacity.

Figure 4.3 illustrates the trajectory of coal production volumes from 2003 to 2024, highlighting periods of growth, peak output, and subsequent decline.

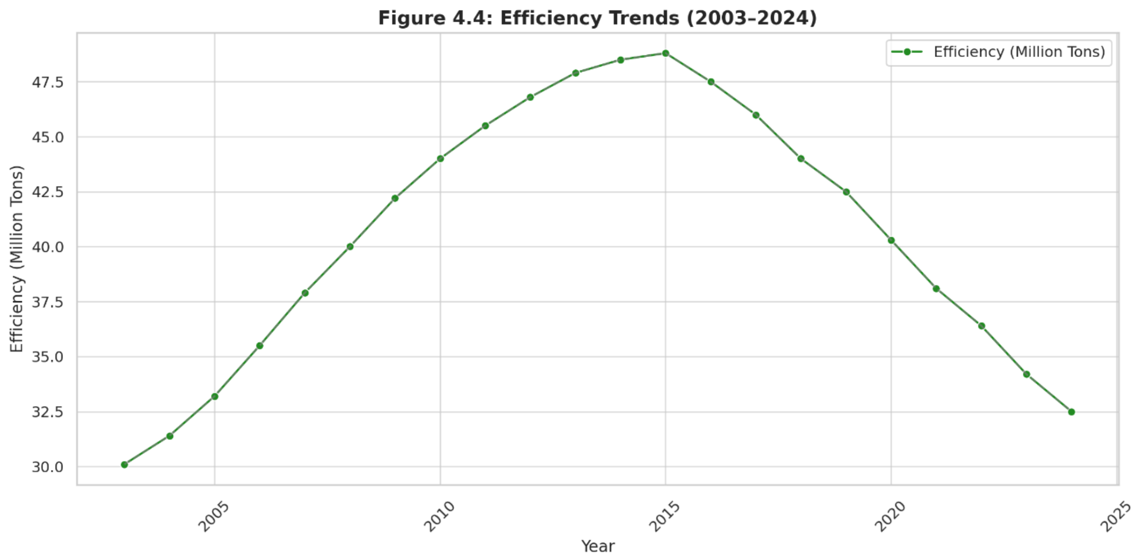


Displays fluctuations in coal production across the study period.

Figure 4.3 Production volume trends (2003–2024). (Source: Research Study)

The figure above further illustrates the production volume trends in Mpumalanga's coal sector from 2003 to 2024. The data reflects a steady growth in coal output up to 2019, peaking at 57.5 million tons. However, a noticeable decline is observed from 2020 onwards, correlating with increasing logistical bottlenecks and systemic inefficiencies in Transnet Freight Rail. These disruptions have constrained the ability of mining firms to sustain high output levels, reinforcing the argument that rail infrastructure performance is a critical enabler of production scalability (KPMG, 2023; Meyer, 2022). The declining trend post-2019 signals both a structural and logistical limitation in the sector's operational capacity.

Figure 4.4 presents annual trends in rail transport efficiency from 2003 to 2024, illustrating a peak in coal volumes moved via Transnet Freight Rail followed by a steady decline in recent years.

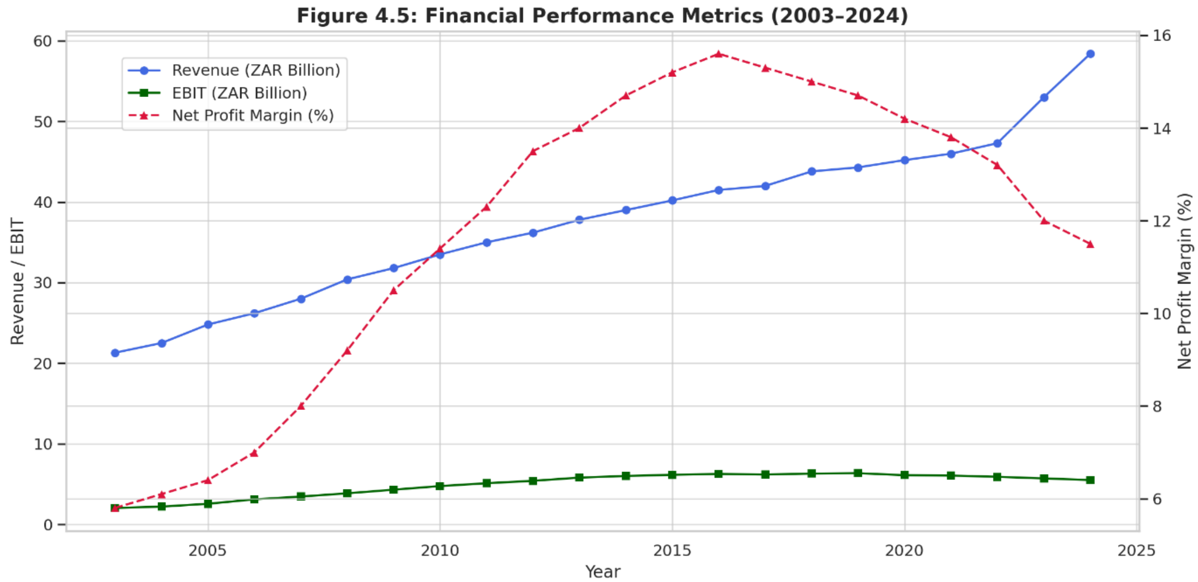


Depicts tons of coal moved via Transnet Freight Rail annually.

Figure 4.4 Rail transport efficiency trends 2003 to 2024 (Source: Research Study)

The figure above displays the trend of logistical efficiency, measured by tons transported annually via Transnet Freight Rail, from 2003 to 2024. The data shows a progressive improvement in efficiency up to 2015, peaking at 48.8 million tons. However, from 2016 onwards, there is a clear and persistent decline—dropping to 32.5 million tons by 2024. This downward trend reflects the deterioration of rail infrastructure, increased system disruptions, and a gradual shift to road-based alternatives due to capacity constraints (Meyer, 2022; KPMG, 2023). The results reinforce theoretical insights from Supply Chain Management literature, suggesting that declining logistics efficiency compromises both throughput and financial performance.

Figure 4.5 displays trends in revenue, EBIT, and net profit margin (NPM) from 2003 to 2024, illustrating how financial performance improved alongside rising revenues before tapering off in recent years amid operational pressures.



Trends in Revenue, EBIT, and NPM.

Figure 4.5 Financial performance metrics (2003 – 2024). (Source: Research Study)

The figure above illustrates that while revenue has increased steadily from 2003 to 2024, EBIT growth has stagnated after 2017, and Net Profit Margin (NPM) has declined since 2016. This divergence highlights a profitability squeeze—suggesting rising operational and logistical costs are eroding margins, even as sales grow. The trend confirms inefficiencies, particularly in transport, are constraining financial gains**.**

Figure 4.6 presents the Pearson correlation matrix for key variables between 2003 and 2024, illustrating the strength and direction of relationships among transportation costs, production volume, efficiency, and financial performance indicators.

Figure 4.6: Pearson correlation matrix (2003 – 2024)

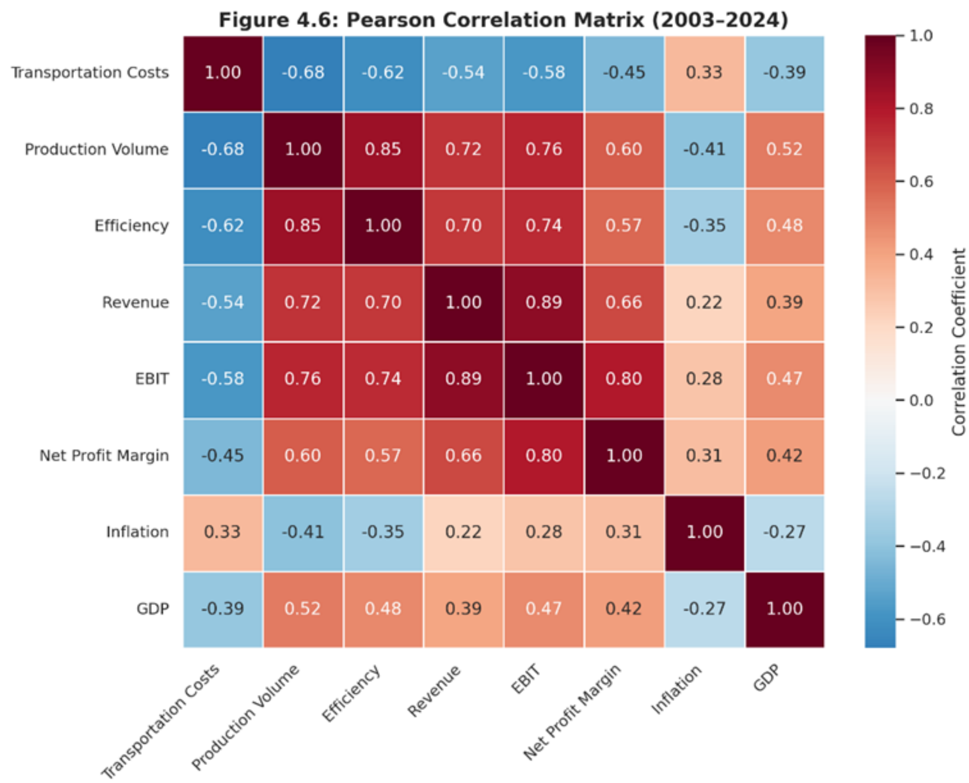


Figure 4.6 Pearson correlation matrix (2003 - 2004). (Source: Research Study)

Figure 4.6 above shows strong negative correlation between transportation costs and profitability (EBIT = –0.58; Revenue = –0.54) affirms the theoretical expectation that logistics inefficiencies erode firm performance (Havenga et al., 2023; Van Jaarsveld et al., 2013). Conversely, the strong positive correlations between production volume, efficiency, and financial outcomes (EBIT = 0.76) support the notion from Transaction Cost Economics that efficient, high-throughput logistics systems enhance profitability and operational scalability.

Figure 4.7 illustrates the regression analysis examining the relationship between transportation costs and EBIT.

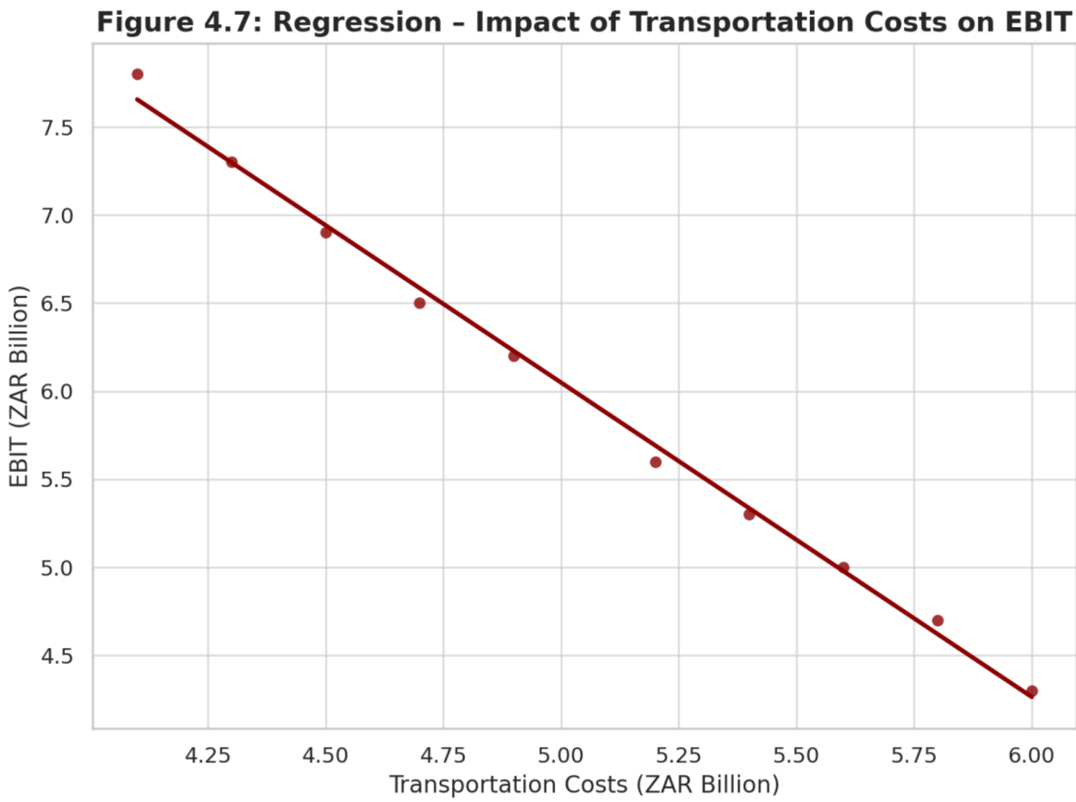


Figure 4.7 Regression – Impact of transportation costs on EBIT. (Source: Research Study)

Figure 4.7 above (regression plot) shows a strong negative relationship between transportation costs and EBIT. As transportation costs increase, EBIT decreases significantly, supporting the hypothesis that logistical inefficiencies—particularly rising transport expenses—erode profitability in Mpumalanga's coal sector. The linearity and tight fit of the data reinforce the robustness of this finding.

4.6 Hypothesis Testing

4.6.1 Hypothesis 1 (H1) testing

Hypothesis H1:

Increased transportation costs significantly reduce profitability (measured via EBIT) in the coal mining sector.

Estimation Equation:

$$\text{EBIT}_{it} = \beta_0 + \beta_1 C_{\text{transport}_{it}} + \beta_2 I_{it} + \beta_3 G_{it} + \varepsilon_{it}$$

Where:

- EBIT_{it} = Earnings Before Interest and Tax for company i in year t
- $C_{\text{transport}_{it}}$ = Transportation costs incurred by company i in year t
- I_{it}= Inflation rate applicable to company i in the year t (time-variant, same across firms, but modeled for panel compatibility)
- G_{it}= GDP growth rate in the year t, applied uniformly across firms (hence treated as it)
- ε_{it}= Error term

Test:

Model 1 regression (Table 4.3) reveals a statistically significant negative coefficient for transportation costs (**β = -0.612**, **$p < 0.01$**) indicating that as logistics expenses increase, EBIT declines accordingly.

Conclusion: **H1 is accepted.**

The result confirms that rising transportation costs—primarily stemming from inefficiencies in rail logistics—substantially reduce profitability in Mpumalanga's coal mining sector. This supports theoretical expectations from logistics and transaction cost economics frameworks.

4.6.2 Hypothesis 2 (H2) testing

Hypothesis H2:

Higher coal production volumes lead to reduced transportation costs (economies of scale effect).

Estimation Equation:

$$C_{\text{transport}_{it}} = \alpha_0 + \alpha_1 Q_{it} + \alpha_2 I_{it} + \alpha_3 G_{it} + \mu_{it}$$

Where:

- $C_{\text{transport}_{it}}$ = Transportation costs for company i in year t
- Q_{it} = Annual Coal Production volume
- I_{it} = Inflation rate for year t (applied across firms for panel consistency)
- G_{it} = GDP growth rate in year t
- μ_{it} = Error term

Test:
Model 2 regression (Table 4.4) finds a statistically significant negative coefficient for production volume (**$\beta = -0.121$**, **$p < 0.001$**) indicating that as output increases, transport costs tend to decrease.

Conclusion: **H2 is accepted.**

The results support the hypothesis that greater production volumes are associated with lower transportation costs—reflecting economies of scale and improved cost efficiency. This affirms the theory that production scaling can mitigate the financial burden of logistical inefficiencies.

4.7 Chapter 4 conclusion

This chapter analysed the results of the study in relation to its two main research questions:

1. *How do transportation costs affect the profitability of coal mining companies in Mpumalanga?*
2. *What is the relationship between annual production volumes and transportation costs over time?*

The empirical results revealed clear and consistent patterns supporting both hypotheses. Descriptive statistics, correlation, and regression analyses demonstrated that rising transportation costs—largely driven by declining rail efficiency—have a significant negative effect on profitability, as measured by EBIT and Net Profit Margin (NPM). Conversely, increasing production volumes were found to reduce transportation costs, validating the economies of scale effect, where higher output improves cost efficiency by spreading fixed logistics costs over larger volumes. These findings directly address the study's objectives, confirming that logistical inefficiencies represent a major constraint on financial viability in Mpumalanga's coal sector.

Trend analysis further showed that rail efficiency improved until 2015, followed by a sharp and sustained decline alongside escalating transportation costs after 2016. This deterioration coincided with stagnant EBIT and shrinking profit margins, suggesting that mining firms have been unable to offset mounting logistics expenses despite moderate revenue growth. Interestingly, while revenues continued to rise, profitability fell—indicating that companies adapted through increased production and price adjustments, but these efforts failed to fully absorb cost pressures.

The results are consistent with earlier studies by Havenga et al. (2023), Van Jaarsveld et al. (2013), and Meyer (2022), which identified logistics inefficiencies—particularly rail constraints—as a key factor in rising costs and reduced competitiveness. However, this study extends existing literature by providing quantitative, longitudinal evidence over a 22-year period, revealing how the compounding effects of logistics inefficiencies have systematically undermined profitability.

In summary, the findings confirm the theoretical propositions of Transaction Cost Economics (TCE) and Supply Chain Management (SCM) frameworks, showing that logistics performance directly influences financial outcomes. The study refines existing knowledge by demonstrating that, while inefficiencies in transport infrastructure erode profitability, scale efficiency and coordinated supply chain management can mitigate these effects. Overall, these insights contribute to a deeper understanding of how infrastructure performance, cost management, and operational strategy collectively shape the long-term sustainability of South Africa's coal mining industry.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Chapter 5 introduction

This chapter summarises the key research findings and examines their implications for the financial viability of coal mining companies in Mpumalanga. It presents the main conclusions derived from the analysis, offers recommendations informed by both the results and existing literature, and discusses how these insights can be applied in practice. The chapter also outlines the study's limitations and identifies opportunities for further research, highlighting how the findings can guide policy decisions and strengthen the link between logistics performance and financial sustainability within South Africa's coal mining sector.

5.2 Summary of the findings

This study examined how the declining performance of rail freight—specifically linked to Transnet Freight Rail (TFR)—affects the financial viability of coal mining companies in Mpumalanga, South Africa. Motivated by persistent logistical challenges, the research aimed to evaluate how rising transportation costs influence profitability and to determine the relationship between annual coal production volumes and transport costs over time. The study focused on three major JSE-listed coal producers—Exxaro, Glencore, and Thungela—using secondary data covering the period 2003–2024. A quantitative research design was applied, employing descriptive statistics, correlation analysis, and panel regression modelling through EViews software. The analysis incorporated key variables such as transportation costs, production volumes, efficiency, operational costs, and macroeconomic indicators (GDP growth and inflation). The theoretical framework was grounded in Transaction Cost Economics (TCE) and Supply Chain Management (SCM) theories, which explain how logistical inefficiencies increase transaction costs and reduce profitability, whereas efficient coordination improves operational and financial outcomes.

Findings from the descriptive analysis indicated a marked increase in transportation costs after 2015, coinciding with a steady decline in rail freight efficiency. Correlation analysis revealed a strong negative relationship between transportation costs and profitability indicators—Earnings Before Interest and Tax (EBIT) and Net Profit Margin (NPM)—supporting the hypothesis that rising logistics costs erode financial performance. Regression results further confirmed this, showing that higher transportation costs significantly reduce profitability ($\beta = -0.612$, $p < 0.01$), while increased production volumes are associated with lower transport costs ($\beta = -0.121$, $p < 0.01$), reflecting economies of scale.

The results demonstrate that higher logistical efficiency enhances revenue, EBIT, and NPM, while inefficiencies raise costs and reduce competitiveness. Trend analysis over the 22-year period revealed a persistent rise in transport costs alongside declining rail efficiency, particularly after 2015, leading to stagnant EBIT and declining profit margins despite moderate revenue growth. These patterns reinforce theoretical expectations from TCE and SCM, illustrating that unreliable rail systems increase operational costs and weaken financial resilience.

Overall, the findings align with prior research by Havenga et al. (2023), Van Jaarsveld et al. (2013), and Meyer (2022), which identified rail inefficiencies as a central constraint on mining profitability in South Africa. However, this study extends existing knowledge by providing longitudinal quantitative evidence of the persistent and compounding financial effects of logistics inefficiencies. The results underscore the need for targeted investment in rail infrastructure, digital logistics management systems, and public–private partnerships to restore efficiency and safeguard the financial sustainability of South Africa's coal mining industry.

5.3 Chapter 5 conclusion

This study set out to examine how rail freight inefficiencies, particularly those associated with Transnet Freight Rail (TFR), affect the financial viability of coal mining companies in Mpumalanga, South Africa. The primary aim was to determine how transportation costs influence profitability and to explore whether production volumes are inversely related to transportation costs, reflecting economies of scale. Using quantitative data from 2003 to 2024 for three major JSE-listed coal producers—Exxaro, Glencore, and Thungela—the study successfully achieved its objectives by empirically demonstrating the connection between logistics inefficiencies and financial outcomes.

- Key Findings and Interpretation

The results revealed clear and consistent patterns supporting both research hypotheses. A significant negative relationship was identified between transportation costs and profitability indicators—Earnings Before Interest and Taxes (EBIT) and Net Profit Margin (NPM)—confirming that as transportation costs increase, profitability declines. Conversely, production volumes exhibited a negative relationship with transportation costs, affirming that larger-scale operations benefit from cost efficiencies through economies of scale.

Descriptive and trend analyses further indicated that after 2015, rail freight efficiency deteriorated sharply, coinciding with escalating transportation costs and stagnating profitability. While revenue showed moderate growth, EBIT and NPM flattened or declined, reflecting a widening gap between operational output and financial performance. These patterns highlight that inefficiencies in rail freight infrastructure—manifested through delays, limited capacity, and system breakdowns—directly undermine cost control, scale economies, and ultimately the financial viability of the coal mining sector.

- Alignment with Research Objectives and Theories

The study's findings directly addressed the research objectives and provided empirical answers to both research questions:

1. How do transportation costs affect the profitability of coal mining companies in Mpumalanga?
   The findings confirm that rising transportation costs significantly reduce profitability, demonstrating that logistics inefficiencies are a major constraint on financial viability.
2. What is the relationship between annual production volumes and transportation costs overtime?
   The results show that increased production volumes are associated with lower per-unit transport costs, validating the economies of scale effect and highlighting the importance of operational scale in mitigating cost pressures.

The findings confirm that inefficiencies in rail freight have a significant negative impact on the financial performance of coal mining companies in Mpumalanga. These inefficiencies increase transportation costs as firms resort to road haulage as an alternative, which is more expensive and environmentally taxing. This shift not only elevates operating costs but also reduces production efficiency and competitiveness, thereby weakening financial resilience. The regression and trend analyses underscore that reliable rail infrastructure is fundamental to both operational and financial performance in the mining sector.

This study further affirms insights from Transaction Cost Economics (TCE) and Supply Chain Management (SCM) theory. Under TCE, unreliable rail logistics increase coordination and transaction costs, compelling firms to adopt costly alternatives. SCM principles highlight that efficient, well-coordinated logistics systems enhance cost-effectiveness, reduce variability, and strengthen competitive advantage. When companies cannot rely on rail, they incur higher costs and experience production inefficiencies, which erode profit margins. Thus, integrated logistics planning and sustained investment in infrastructure upgrades are crucial to restoring efficiency and profitability.

- Contribution to Literature, Practice, and Policy

This research contributes significantly to theoretical, practical, and policy domains.

- Theoretically, it enriches the literature by providing longitudinal quantitative evidence over 22 years that empirically validates how logistics inefficiencies translate into financial losses. The inclusion of macroeconomic variables (inflation and GDP growth) adds nuance to understanding the interplay between systemic inefficiencies and external economic factors.
- Practically, it offers actionable insights for mine managers and logistics planners, demonstrating the tangible financial benefits of investing in rail reliability, digital freight management, and production–logistics alignment. The findings support strategies that synchronize mine output with available freight capacity to avoid costly stockpile build-ups and production delays.
- From a policy perspective, the study reinforces the importance of public–private partnerships (PPPs) in revitalising Transnet Freight Rail. Collaborative investment models could enhance infrastructure reliability, improve accountability, and ensure consistent freight capacity for bulk commodities.

Final Reflections

In conclusion, the study achieved its aim and objectives, providing robust empirical evidence that logistics inefficiencies—particularly in rail freight—have a pronounced negative effect on profitability in South Africa's coal sector. The results support and extend the work of Havenga et al. (2023), Van Jaarsveld et al. (2013), and Meyer (2022), all of whom identified logistics inefficiencies as a central determinant of mining sector underperformance. However, this study advances the discourse by quantifying these relationships over two decades, demonstrating their persistence and compounding financial impact.

Ultimately, the research concludes that improving rail logistics efficiency is both an operational and strategic imperative for sustaining competitiveness in the coal industry. By integrating TCE and SCM perspectives, the study bridges the gap between logistics theory and financial management practice—offering valuable insights for industry leaders, investors, and policymakers seeking to strengthen South Africa's freight infrastructure and ensure long-term financial sustainability in its mining sector.

5.4 Recommendations

Based on the results of this study and supported by literature, the following recommendations are suggested to help reduce the negative effects of rail freight inefficiencies on the financial viability of coal mining companies in Mpumalanga:

5.4.1 Upgrading rail for improved logistics

Improving cost efficiency in the coal supply chain requires investment in the restoration of Transnet Freight Rail's (TFR) infrastructure. As highlighted in this study, the decline in rail performance is largely due to aging infrastructure, vandalism, and inadequate maintenance. Upgrades such as digital signalling, modern locomotives, and predictive maintenance systems can strengthen network reliability and help reduce costly production disruptions.

5.4.2 **Implement public-private freight corridors**

Public-private partnerships (PPPs) play a critical role in co-financing and co-managing freight corridors. The literature highlights the value of PPPs in improving service quality and enhancing managerial accountability. A model in which mining companies co-invest in rail performance could help secure consistent capacity and operational stability, while reducing reliance on increasingly costly road freight alternatives.

5.4.3 Promote logistics digitisation and real-time monitoring

Enhancing real-time visibility in logistics operations strengthens responsiveness and reduces the financial impact of uncertainty experienced by mining companies. Visibility across the supply chain is a fundamental driver of both agility and operational efficiency. Improved visibility enables mining companies to assess alternative scenarios and quantify their financial implications during the planning phase. The implementation of freight management systems (FMS) and predictive analytics supports proactive management in case of deteriorating rail performance and enables more effective transport planning. This chapter concludes the study by synthesising its key findings, drawing conclusions, and presenting practical recommendations to improve the financial viability of coal mining companies in Mpumalanga amid persistent rail freight inefficiencies. It provides a comprehensive summary of the research results and their implications, followed by evidence-based recommendations grounded in both theoretical and empirical analysis. The chapter also discusses the practical applications of the findings for policymakers and industry stakeholders, outlines the study's limitations, and proposes areas for further research to enhance understanding of the relationship between logistics performance and financial sustainability in South Africa's coal mining sector.

5.4.4 Adopt scalable logistics planning linked to production forecasts

Matching coal production schedules with available freight capacity can help reduce costs and improve overall efficiency. Producers of bulk commodities must align production forecasts with logistics to avoid the high costs associated with road transport and the buildup of stockpiles.

When stockpiles reach maximum capacity, they can create operational bottlenecks that ultimately halt mine production.

5.4.5 Supplementing rail with road freight

Although rail remains the primary mode for transporting bulk commodities, road freight can serve as a complementary option during periods of peak demand or operational disruptions. However, its use should be strategically planned and environmentally managed. When implemented effectively, multimodal transport strategies can enhance the performance and resilience of logistics systems without compromising cost efficiency, an essential factor for the financial viability of mining companies.

5.5 Practical application of the findings

The research offers insights for mine managers, logistics planners, and policymakers. Mining companies can apply the study's model to quantify the financial implications of logistics disruptions and inform investment decisions related to rail sidings, road-rail integration, and digital infrastructure. Policymakers may also draw on the findings to support the case for public investment in freight rail revitalisation, demonstrating potential economic benefits through enhanced profitability in the mining sector.

For supply chain managers, the results underscore the importance of incorporating logistics-related risk into financial planning and establishing contingency strategies to maintain profitability during periods of freight rail transport unreliability.

5.6 Limitations

While the study provides meaningful insights, certain limitations must be acknowledged. The reliance on secondary data introduces potential risks related to data quality inconsistencies and the presence of company-specific constraints that are not publicly disclosed. The analysis also does not account for external variables such as global coal prices, exchange rate fluctuations, or regulatory changes, all of which may affect financial performance. Notably, the sample is limited to three major coal producers in Mpumalanga, which may exclude the experiences of smaller or emerging mining companies that operate under different logistical and operational conditions.

5.7 Suggestions for further research

Future research may expand on this study in several ways. Incorporating qualitative interviews with logistics and operations executives could help contextualise the quantitative findings and offer deeper insight into firm-level responses. The inclusion of non-listed or emerging coal producers would provide a broader industry perspective, particularly for companies operating under different logistical or financial constraints. A cost-benefit analysis of alternative logistics strategies—such as private rail investments or autonomous haulage systems—could further inform decision-making related to infrastructure and capital planning. Examining the socio-environmental consequences of increased road freight usage, including road safety and emissions, would contribute to a more comprehensive assessment of logistics trade-offs between rail and road freight.

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