ANALYSIS OF SUPPLY CHAIN ISSUES IN RAIL TRANSPORT WITH INDIAN CONTEXT

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Submitted by

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DECLARATION OF ORIGINALITY

I hereby declare that the research work presented in this thesis titled *"**Analysis of Supply Chain Issues in Rail Transport with Indian Context**"* is an original and authentic work carried out by me under the supervision of **Dr. Vipin**, Professor, Department of Mechanical Engineering, Delhi Technological University, Delhi, and **Dr. Ashish Agarwal**, Professor, School of Engineering & Technology, IGNOU, New Delhi, for the award of the ***Doctor of Philosophy*** degree in ***Mechanical Engineering***. The work presented in this thesis has not been submitted to any other university or institution for the award of any degree or diploma.

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SUPERVISOR'S CERTIFICATE

This is to certify that the Ph.D. thesis entitled **"Analysis of Supply Chain Issues in Rail Transport with Indian Context"** being submitted by Mr. Manoj Kumar, Roll No. 2K18/PHDME/31, for the award of the degree of Doctor of Philosophy in Mechanical Engineering, Delhi Technological University, Delhi, India, is a bonafide record of original research work carried out by him under my guidance and supervision. The work presented in this thesis has not been submitted to any other university or institution for the award of any degree or diploma.

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ABSTRACT

Supply Chain Management (SCM) is essential for facilitating the effective movement of commodities, services, and information throughout intricate networks. In Indian rail transport, supply chain management is essential for linking areas and fostering economic development. Indian Railways has substantial obstacles in optimizing its supply chain, including antiquated infrastructure, regulatory impediments, and insufficient stakeholder collaboration.

This study uses a multifaceted approach that includes the Analytic Hierarchy Process (AHP) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to rank important parts of the supply chain, like unified systems, financial behaviour, and managerial points of view. Also, Modified Total Interpretive Structural Modelling (M-TISM) and fuzzy MICMAC analysis are used to look at how problems like market volatility, stakeholder participation, and government laws affect each other.

Partial Least Squares Structural Equation Modelling (PLS-SEM) is also used to look at how things like top management commitment, supply chain cooperation, and supply chain performance are connected. The sample size for PLS-SEM comprises 145 respondents, mostly material suppliers to Indian Railways, including CEOs, managers, and administrators. The identified elements are Top Management Commitment (TMC), Supply Chain Collaboration (SCC), Supply Chain Management Rail Transport (SCMRT), and Supply Chain Performance (SCP). These structures are assessed for their influence on overall supply chain efficiency.

The results indicate that top management commitment and supply chain collaboration substantially affect supply chain performance, with financial behavior and regulatory frameworks identified as critical success factors. Furthermore, obstacles such as inadequate stakeholder participation and regulatory compliance challenges are emphasized. The study uses complex decision-making models and PLS-SEM analysis to give strategic insights that will help make the Indian Railways' supply chain more flexible and responsive. This will create a framework for improving operational efficiency and sustainability in the transportation sector.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Modern corporate operations depend heavily on supply chain management (SCM), which coordinates and administers a network of linked companies that provide goods and services to final consumers. It covers the whole process, from sourcing raw materials to product delivery, to ensure the right product gets to the right location at the right time for the best price. Over the last several decades, the global trade scene has changed significantly, and Supply Chain Management (SCM) has been essential to boosting competitiveness and efficiency. The way that Supply Chain Management (SCM) lowers operating costs, increases customer happiness, and improves overall company performance highlights how important it is. Over time, the idea of supply chain management (SCM) has changed, concentrating increasingly on integrating many services, including manufacturing, distribution, and customer service, rather than just transportation and inventory management. This development stems from the complexity of supply chains and the necessity for companies to manage their supply networks through a more integrated and strategic approach. A company's capacity to satisfy client needs, save expenses, and preserve a competitive edge in an international market is directly impacted by the efficiency of its supply chain management (Beamon, 1999).

SCM was traditionally thought of as essentially a logistical function that dealt with the movement and storage of products. But in the last several decades, the idea has changed significantly. SCM has expanded in scope and is now integrated with marketing, finance, and human resources, among other company areas. In a globalized market where companies must manage a network of suppliers, manufacturers, and distributors across many nations and regions, this progression reflects the growing complexity of supply chains. Technology development is one of the main forces driving SCM's progress. Supply chain management has changed because of the widespread use of digital technologies, including artificial intelligence, big data analytics, and enterprise resource planning (ERP) systems. With the use of these technologies, businesses can see their supply chains in real time, which empowers them to predict disruptions, make data-driven choices, and react swiftly to demand changes.

SCM's contribution to raising customer satisfaction is yet another important feature. Customers need prompt, dependable, and economical delivery of goods and services in today's cutthroat marketplace. Meeting these expectations requires SCM to make sure the correct items are accessible at the appropriate time and location. Effective supply chain management not only raises customer happiness but also strengthens brand loyalty and promotes company expansion. The fact that SCM may lead to cost savings further emphasizes its strategic significance. By streamlining their supply chains, businesses can reduce waste, inventory levels, and transportation costs. Furthermore, organizations may negotiate better terms with suppliers, which reduces costs and boosts profitability by using strategic sourcing and supplier relationship management techniques.

Additionally, SCM is essential to risk management. Supply networks in a global economy are vulnerable to a variety of hazards, including natural catastrophes, political unrest, and economic volatility. Supply chain operations must be maintained, so effective supply chain management (SCM) entails detecting possible hazards, evaluating their implications, and creating mitigation plans. SCM is also facing new possibilities and difficulties because of the increased focus on sustainability. More companies are being held accountable for their supply chains' environmental and social impacts. Achieving sustainable supply chain management entails implementing eco-friendly techniques, including cutting carbon emissions, making the best use of available resources, and guaranteeing moral labor standards are followed throughout the supply chain. Companies can build long-term value and competitive advantage by incorporating sustainability into SCM and meeting stakeholder expectations and legal needs.

1.2 Definition and Overview of SCM

Supply chain management, or SCM, is an essential discipline in corporate operations that deals with sourcing, producing, and distributing goods and services from raw materials to end users. It also entails managing and coordinating these activities. Supply chain management (SCM) seeks to optimize the movement of resources—including money, information, and materials—through integrated operations including distribution, transportation, production planning, and procurement (Christopher *et al*., 2023).

The importance of supply chain management (SCM) has significantly increased in tandem with market globalization and supplier network complexity. Businesses trying to stay competitive in a worldwide market now consider effective supply chain management to be a critical differentiator. It enables businesses to satisfy client expectations, save expenses, and adapt to changes in the market (Chopra, 2019).

Including technological integration, continuous improvement, and strategic alignment, supply chain network management (SCM) takes a comprehensive approach. To achieve advantages for all parties involved in the supply chain, cooperation is essential (Bowersox *et al*., 2013). Because SCM ensures that things are accessible when and where they are needed, it plays a critical role in guaranteeing customer satisfaction. Significant consumer discontent and corporate loss may result from supply chain delays or interruptions (Christopher, 2000). Because it allows for more visibility, real-time monitoring, and predictive analytics, technology has grown in significance in supply chain management. Supply chain management software, IoT devices, and ERP systems are examples of technologies that have increased operational efficiency and response to market volatility.

Corporate social responsibility and sustainability are two more areas where SCM is developing. Businesses are being held accountable for the social and environmental effects of their supply chains, leading to a move toward more sustainable practices. When moving people and products over large distances, rail transportation is an essential means of transportation. Indian Railways is a major contributor to India's economy, commerce, and regional development. It is one of the biggest and most comprehensive rail networks globally (Ministry of Railways, 2023).

Supply chain management (SCM) is a complex field that is essential to the success of contemporary companies. To maximize the flow of products, information, and funds and, ultimately, increase customer satisfaction and competitive advantage, it entails the strategic coordination of numerous company processes. In India especially, rail transit is an essential means of tying together disparate areas, promoting trade and business, and bolstering the country's economy and progress.

1.3 Importance of SCM in Global Trade

Supply Chain Management (SCM) is very significant in global commerce for several reasons. Firstly, supply chain management (SCM) enhances the whole process of transporting products across various nations, guaranteeing cost-effectiveness and punctual delivery. Operating in numerous locations is vital for firms as it directly affects their competitiveness in varied marketplaces.

Furthermore, supply chain management (SCM) plays a crucial role in effectively handling the intricacies and potential hazards linked to international commerce. International supply chains include a multitude of participants, diverse legal frameworks, and the possibility of interruptions. Efficient supply chain management (SCM) offers comprehensive oversight and authority over the whole supply chain, enabling firms to effectively address these difficulties and minimize risks.

Furthermore, supply chain management (SCM) improves firms' capacity to effectively fulfill the varied and swiftly evolving requirements of consumers on a worldwide scale. Agility and reactivity are crucial in today's fast-paced industry. Supply Chain Management (SCM) is the process of synchronizing supply networks with market needs. Its goal is to ensure that items are readily accessible at the right time and place, hence enhancing customer satisfaction and loyalty.

Additionally, Supply Chain Management (SCM) facilitates the implementation of global business strategies such as offshore, outsourcing, and lean manufacturing. Effective implementation of these methods requires meticulous coordination and oversight of the supply chain, a function facilitated by supply chain management (SCM). According to (Bowersox *et al*., 2013), it is a crucial part of worldwide corporate operations.

Supply chain management (SCM) also plays a role in ensuring the long-term viability and environmental responsibility of multinational corporate operations. Sustainable supply chain management (SSCM) incorporates environmental and social factors into supply chain processes, fostering environmentally conscious and socially responsible commerce. Implementing sustainable supply chain management (SSCM) techniques improves the company's image, ensures compliance with regulations, and attracts environmentally concerned customers.

Moreover, supply chain management (SCM) promotes cooperation and alliance among actors in global commerce. Close coordination between suppliers, manufacturers, logistics providers, and consumers across multiple nations is necessary due to the linked structure of global supply chains. An effective supply chain management (SCM) strategy establishes a unified and interconnected approach that fosters trust, enhances communication, and generates value for all parties involved (Beamon, 1999).

SCM is essential in global commerce since it efficiently controls costs, mitigates risks, satisfies market expectations, facilitates company plans, encourages sustainability, and cultivates teamwork. With the ongoing expansion of globalization and the increasing complexity of supply networks, the importance of supply chain management (SCM) in ensuring the success and long-term viability of global commerce will undoubtedly grow.

1.4 Historical Development of SCM

The concept of supply chain management (SCM) has undergone significant advancements over time, primarily due to technological advancements, changes in business practices, and global economic trends. Even though the term "supply chain management" was not widely recognized until the latter half of the 20th century, the fundamental concepts that undergird SCM have their roots in a much earlier era of history.

The origins of supply chain management can be traced back to the early days of trade and commerce when societies first began to engage in the systematic manufacturing and distribution of products. Supply chain management was implemented at this time. Early forms of supply chain management were evident during the development of infrastructure in ancient civilizations such as Mesopotamia, Egypt, and China. The construction of highways, storage facilities, and ports was among the early forms of supply chain management, all of which were intended to facilitate the movement of commodities over extensive distances. These early endeavours established the foundation for more intricate supply chain methods by addressing the critical requirement of effectively managing resources, logistics, and trade routes. They achieved this by addressing the fundamental need.

During the Industrial Revolution of the 18th and 19th centuries, there was a significant advancement in the development of supply chain management methods. The emergence of mass production, which was driven by steam engines and automated industrial processes, necessitated the development of more structured and efficient systems to manage the flow of raw materials and completed items.

In the early 20th century, Frederick Winslow Taylor was the first to introduce the concept of "scientific management," which prioritized productivity and efficacy in industrial operations. Even though Taylor's concepts were not formally recognized as supply chain management (SCM), they laid the groundwork for current supply chain practices by prioritizing manufacturing process optimization and waste reduction.

Around the turn of the 20th century, logistics emerged as a distinct field of study and practice. It was inextricably linked to supply chain management (SCM), which would later be referred to as supply chain management. During World War I and II, the logistics of conveying personnel, equipment, and supplies over extensive distances became an essential military function. This resulted in enhancements to inventory management, warehousing, and transportation (Bowersox *et al*., 2013). During both conflicts, the logistics of transporting these items became a critical military function. The term "logistics" began to be employed more frequently in the business sector following the conflicts. This was particularly true in sectors such as manufacturing, retail, and transportation, where the company's performance was contingent upon the efficient flow of products.

Another factor that contributed to the development of logistics management was the economic growth that occurred in the 1950s and 1960s following World War II. (Bowersox and Closs 1996) assert that the expansion of global commerce, which was driven by advancements in transportation and communication technology, led to the development of supply networks that were more intricate and necessitated more sophisticated management strategies. During this period, the just-in-time (JIT) inventory system, which was developed by Japanese businesses such as Toyota, began to influence supply chain procedures worldwide. (Ohno, 1988) emphasized that JIT was designed to optimize production efficiency and reduce inventory levels by closely aligning production schedules with demand (Bowersox *et al*., 2013).

Companies began to recognize the importance of consolidating multiple operations, including procurement, distribution, and manufacturing, into a unified and comprehensive process during the 1980s, which was a critical decade in the development of supply chain management (SCM). Initially, the term "supply chain management" was coined by academicians and consultants to describe this integrated strategy, which aimed to optimize the entire supply chain rather than individual components. This optimization technique aimed to optimize the entire supply chain. Furthermore, during this period, globalization was on the rise, and businesses were expanding their supply chains beyond national borders. Furthermore, this underscored the necessity of establishing effective supply chain management protocols. In the 1990s, the advancements in information technology (IT) facilitated the exchange of data and communication among supply chain participants in real-time, thereby revolutionizing supply chain management (SCM) (Bowersox *et al*., 2013).

The introduction of Enterprise Resource Planning (ERP) systems enabled companies to establish connections between their internal operations, including production, inventory management, and order processing, and external partners. This led to a supply chain that was more responsive to consumer requirements and more visible. These technical advancements established this framework, which laid the groundwork for modern supply chain management strategies that rely primarily on data analytics, automation, and digital platforms.

At the dawn of the 21st century, supply chain management (SCM) experienced further advancements, fuelled by the digital revolution and the accelerated pace of globalization. Numerous factors have influenced contemporary supply chain management strategies, such as the increasing importance of sustainability, the expansion of global procurement, and the emergence of e-commerce. A company's success in the highly competitive and dynamic business environment of today is contingent upon the successful management of complex global supply chains. Companies are currently operating in contexts that are highly competitive and dynamic. Modern supply chain management prioritizes adaptability, flexibility, and resilience in response to adversities, including economic crises, natural disasters, and pandemics, in addition to cost reduction and efficiency enhancement.

Supply chain management (SCM) is currently in a state of perpetual evolution because of the introduction of new technologies such as the Internet of Things (IoT), blockchain, and artificial intelligence (AI). The next iteration of the supply chain management (SCM) revolution is being driven by these technologies, which provide enhanced visibility, automation, and predictive capabilities throughout the supply chain. There is little doubt that the strategic function of supply chain management (SCM) will become more prominent as firms continue to navigate the challenges presented by globalization, sustainability, and digital disruption.

The historical development of supply chain management (SCM) demonstrates a continuous progression from basic logistical techniques to a discipline that is highly integrated and offers strategic guidance. Supply chain management remains a critical component of the success and innovation of businesses, even though it is constantly adapting to the changing global landscape.

1.5 Overview of Rail Transport

1.5.1 Definition and Importance of Rail Transport

Rail transport, sometimes referred to as railroads or trains, is a kind of transportation in which cargo and people are transported on wheels over railroad tracks. It is among the most effective modes of public transportation, especially for large and long-distance freight transports. Rail transportation is propelled by locomotives that may run on steam, diesel, or electricity and is based on a permanent infrastructure made up of tracks, stations, and terminals. In addition to the actual rails and trains, the infrastructure for rail transportation usually consists of signal systems, communication networks, and maintenance facilities—all of which are necessary for the safe and efficient functioning of the system (Beamon, 1999).

Rail transportation is distinguished by its tremendous efficiency in moving large numbers of people and cargo across vast distances. In contrast to automobile transportation, which must contend with traffic jams and wear on public roads, rail transportation has access to a dedicated track that facilitates continuous, smooth travel. Because of its effectiveness, it is an essential part of networks for both freight logistics and passenger transportation. In many countries, railways are an essential component of the national infrastructure, and they are important for economic integration and growth. The Value of Railroad Transportation The efficiency, sustainability, and financial advantages of rail transportation make it a vital component of the worldwide transportation network.

1.5.2 Efficiency and Capacity

Railways are well-known for having a high capacity, which makes them perfect for transporting big loads of people and cargo. The load on road networks may be greatly reduced by using a single train, which can transport as much cargo as hundreds of vehicles. For sectors like manufacturing and retail that depend on just-in-time (JIT) delivery systems, rail transport is especially crucial because of its large capacity and ability to keep regular schedules. Furthermore, particularly when traveling large distances, the efficiency and dependability of rail transportation may often outperform that of other forms.

1.5.3 Environmental Sustainability

Rail is one of the most ecologically friendly forms of transportation. In comparison to road or air transportation, trains—especially those driven by electricity—produce far less greenhouse gas emissions per ton-mile or passenger-mile. Using electric trains may lessen reliance on fossil fuels, which will aid in the fight against climate change. In addition, compared to roads, railways have a reduced land footprint proportional to their capacity, which helps conserve land and lessens the disturbance of habitat (Slack, 2018). Rail transportation plays an increasingly crucial role in attaining sustainable mobility as worldwide efforts to cut carbon emissions escalate.

1.5.4 Economic Effects

Rail transportation has a significant economic impact. Because they provide an effective method of moving people and products, which promotes trade and commerce, railways are essential to the growth of regional and national economies. Because it increases market accessibility, lowers transportation costs, and boosts productivity, the construction of rail infrastructure often promotes economic growth. In addition, railroads not only support the operation and upkeep of the train network itself, but also foster employment growth in other sectors such as manufacturing, logistics, and tourism.

1.5.5 Connectivity and social integration

Rail transportation fosters social integration by connecting rural and urban areas, as well as various regions and nations. For people in many countries who may not be well served by other forms of transportation, trains are crucial in offering accessible and reasonably priced transit alternatives. In addition to facilitating travel and job mobility, this interconnectedness fosters regional development and tourism. Millions of people in highly populated nations like India rely on the railway network as a lifeline, and it is essential to social and economic integration.

1.5.6 Dependability and Safety

With fewer collisions and deaths than driving, rail transportation is often seen to be safer than driving. Rail transportation's permanent rails and sophisticated signaling systems add to its dependability and safety. Furthermore, compared to air or road transportation, railroads are less vulnerable to weather-related delays, making them a trustworthy choice for both passenger and freight transportation. To sum up, rail transport is an essential means of transportation that has many advantages, such as great efficiency, environmental sustainability, economic effect, improved connection, and safety. It is especially crucial in nations with sizable populations and geographical regions since they provide the framework for both passenger and freight transportation. The importance of rail transportation in facilitating efficient and sustainable transportation networks will only increase as concerns about the environment and urbanization continue to spread throughout the world (Bowersox *et al.*, 2013).

1.6 Historical Evolution of Railways in India

India's railway history is an intriguing voyage that captures the nation's political, social, and economic changes. The Indian Railways has been essential in determining the course of the country's growth, from its founding under British colonial control to its present standing as one of the biggest railway networks in the world.

The British Era (1853–1947), The Indian Railways have their roots in the British colonial era, around the middle of the 1800s. On April 16, 1853, the first railway line in India was opened, spanning 34 kilometers from Bombay (now Mumbai) to Thane. With the British aiming to establish a railway network mainly to aid the flow of raw commodities from the interior of India to ports for sale to Britain, this event signaled the start of a new age in transportation. The economic and geopolitical objectives of the British colonial authority propelled the early railway network growth. Under a system known as "guaranteed returns," whereby the British government guaranteed a defined return on money spent on railway projects, British private businesses funded the building of railway lines in the main. Major towns, ports, and industrial hubs across the subcontinent were connected by almost 40,000-kilometer (Mentzer *et al*., 2001).

1.6.1 Indian railway network by the end of the 19th century

During this time, the British used the railroads as a vital instrument to seize control of and profit from India's abundant resources. While the import of British manufactured products into India helped develop a colonial economy that was reliant on British industry, the transfer of commodities such as cotton, coal, and cereals to ports aided the export of raw resources to Britain. But the railroads also had unforeseen repercussions. For example, they united many groups and regions in India, which eventually aided in the emergence of nationalist movements.

1.6.2 Nationalization and Expansion during the Post-Independence Era (1947-1980)

The Indian Railways saw major changes after India gained independence in 1947. The nationalization of the railroads in 1951, which placed state authority over all privately held railways, was one of the first significant actions made by the newly established government. By taking this action, the railroads would be able to support national development objectives as opposed to private enterprise profit margins. The railway network underwent significant investment in renovation and development throughout the post-independence era. The construction of railroads was given top priority by the Indian government to advance social justice, regional integration, and economic progress (Bowersox *et al*., 2013). To link isolated and neglected areas, especially in the northeast and south of the nation, new railway lines were built. Along with network expansion, higher-quality service delivery was prioritized, with quicker trains, better facilities, and more amenities for passengers introduced.

Indian Railways was also a major contributor to the nation's industrialization at this time. One of the main factors influencing India's economic development was the transportation of bulk commodities, including steel, coal, and iron ore. In addition, the railroads became a significant employer, providing millions of jobs and assisting in the social and economic advancement of large portions of the populace.

1.6.3 Technological Advancements and Modernization (1980–2000)

Significant technical developments and modernization initiatives within Indian Railways. The booking of tickets underwent a radical transformation when computerized reservation systems were introduced in the middle of the 1980s, increasing accessibility and efficiency (Agrawal, 2018). Major railway lines were also electrified at this time, increasing train efficiency and speed and lowering dependency on fossil fuels. In addition to electrification, the Indian Railways began concentrating on developing high-speed trains and improving rail infrastructure. An important turning point in the history of passenger rail services was the 1988 launch of the Shatabdi Express, India's first superfast train. To improve connections and shorten travel times, the railroads have made investments in the building of new bridges, tunnels, and tracks (Cachon & Lariviere, 2005). Globalization and economic liberalization in the 1990s presented Indian Railways with both new possibilities and problems. The deeper India's integration into the world economy, the greater the need for freight services. In response, the railroads implemented programs including containerization and the creation of special freight lanes to enhance freight services. The goal of these initiatives was to increase rail transportation's competitiveness and capacity to satisfy the needs of a quickly expanding economy.

1.6.4 Current Trends and Upcoming Opportunities (2000–Present)

Indian Railways has persisted in its development in the twenty-first century, emphasizing high-speed rail, sustainability, and modernization. The launch of India's first semi-high-speed train, the Vande Bharat Express in 2019, and the Gatimaan Express in 2016 are examples of the continuous attempts to improve the comfort and speed of passenger services. These changes are part of a larger effort to update the railway system and make it compliant with international norms.

An important change in India's freight transportation policy is the creation of designated freight corridors (DFCs), such as the Eastern and Western DFCs. These corridors are intended to increase the effectiveness of freight transportation while easing traffic on the current passenger lines. The DFCs are anticipated to be vital in assisting India's industrial development and foreign commerce by offering quicker, more dependable, and more affordable product transportation.

Indian Railways has also made sustainability a major area of concern. Efforts to lessen the environmental effect of train operations include projects like the installation of bio-toilets, enhanced electrification, and the use of renewable energy. The railways align with India's larger climate change ambitions because they have set high goals for improving energy efficiency and becoming carbon neutral. In the future, Indian Railways is expected to be a key player in the country's growth. Modernizing India's transportation infrastructure will be greatly aided by the proposed construction of high-speed rail networks, such as the Mumbai-Ahmedabad line (Cachon & Lariviere, 2005). Furthermore, it is anticipated that additional investments in digital technology will improve the efficiency, safety, and dependability of rail services. These expenditures include the deployment of sophisticated signaling systems and real-time monitoring. India's railway system has developed historically because of a dynamic process of expansion, modernization, and adaptation to changing social, technical, and economic environments. Indian Railways has had a significant impact on the country's development, both from its colonial beginnings and as an essential part of its infrastructure today. The nation's railroads will always be a vital component of its transportation network and a force behind economic development as it expands and changes.

1.7 Role of Railways in India's Economy

Indian Railways (IR), operated by the Ministry of Railways, is India’s national railway system and serves as a vital public service. It manages the world’s fourth-largest railway network, with a route length of 68,155 km (42,350 mi) as of March 2019. As of April 1, 2020, 58.49% of the network, or 39,866 km (24,772 mi), has been electrified using 25 kV 50 Hz AC electric traction.

In the fiscal year ending March 2019, IR transported 844 crore (8.44 billion) passengers and 123 crore (1.23 billion) tonnes of freight. The system operates 13,523 passenger trains daily, covering both long-distance and suburban routes across 7,321 stations in India. Mail or Express trains, the most common services, run at an average speed of 50.6 km/h (31.4 mph), while suburban EMUs have an average speed of 37.5 km/h (23.3 mph). Ordinary Passenger Trains, including mixed services, average 33.5 km/h (20.8

mph). The Vande Bharat Express, India's fastest train, reaches speeds of up to 180 km/h (110 mph).

In the freight sector, Indian Railways operates over 9,146 trains daily, with an average speed of 24 km/h (15 mph). The maximum speed of freight trains ranges from 60 to 75 km/h (37 to 47 mph), depending on axle load, while specialized container trains can reach a top speed of 100 km/h (62 mph).

As of March 2019, Indian Railways' rolling stock included 289,185 freight wagons, 74,003 passenger coaches, and 12,147 locomotives. The organization also owns several locomotive and coach production facilities across India. As the world's eighth-largest employer, Indian Railways had 1.227 million employees as of March 2019.

The nation's infrastructure relies heavily on the rail transport system in India, which makes it easier to transfer people and products across long distances. The administration of the supply chain, which includes several procedures including purchasing, shipping, and inventory control, is one of the system's primary features. Numerous issues with supply chain management have been plaguing the Indian railway sector. Several primary difficulties have been found, including inefficiencies in the procurement process, inadequate accountability, and a deficiency of strategic collaborations with suppliers. High expenses, protracted cycle times, and low value generation for all parties involved have resulted from this. According to research, the Indian railway sector's present procurement procedures are not set up to promote long-term strategic alliances with suppliers. This has led to a "arms-length" approach to supplier partnerships, where transactional rather than cooperative agreements are prioritized. The public procurement systems, which often encounter comparable problems, might benefit from the lessons learned from the supply chain management difficulties faced by the Indian railway sector. Effective supply chain management has also been highlighted as being crucial to the Indian retail industry, especially to the organized and unorganized food sectors.

As per (Raghuram & Ravilochanan, 2014), because of their critical role in the nation's economic growth, the Indian Railways are sometimes referred to as the nation's lifeblood. India's railway network, which is among the biggest globally, plays a vital role in facilitating the transportation of products and people across the country's vast and varied terrain. It influences many different areas of the economy, including commerce, industry, employment, and regional development.

Streamlining Trade and Business is an essential facilitator of trade and business in India is Indian Railways. An integral part of India's supply chain infrastructure, the vast railway network makes it easier to transport commodities across the nation. Bulk commodities including coal, iron ore, cement, and agricultural products are among the many goods carried by the nation's railways. Rail transport is a favoured route for sectors that depend on the efficient and timely delivery of raw materials and completed goods due to its capacity to move huge volumes of commodities across great distances at comparatively cheap rates. The function that railroads play in facilitating trade and commerce is anticipated to be further enhanced with the implementation of dedicated freight corridors (DFCs). According to (Chopra, 2019), these corridors are intended to carry products more quickly, reliably, and efficiently while cutting down on transit times and logistical costs. Exports are expected to increase and Indian companies will become more competitive in the global market as a result of the DFCs' improved connection between important industrial clusters and ports.

The movement of raw materials and completed items in India's industrial sector is largely reliant on the railroads. Railways are used by industries like steel, cement, and petroleum products to transport large quantities of commodities from manufacturing sites to ports and markets. To keep the supply chain running smoothly and make sure that industries can fulfill their production goals, these commodities must be moved efficiently.

Additionally, the railroads foster the development of special economic zones (SEZs) and industrial corridors. The connectivity that these areas provide draws investment, which in turn spurs the emergence of new companies and the generation of employment. It is anticipated that the government's efforts to modernize and extend the railway network, particularly via the construction of high-speed rail and DFCs, would further propel economic and industrial development.

Almost a million people get direct work from Indian Railways, making it one of the biggest employers in the nation. A broad spectrum of professions, from engineers and technicians to frontline workers and administrative personnel, make up the enormous workforce. Millions of households depend heavily on the jobs that the railroads provide, especially in rural and semi-urban regions where there may not be many other options for work. Because of the many auxiliary sectors that provide products and services to the railway network, the railroads not only provide direct employment but also indirect jobs. These sectors include producers of locomotives, wagons, rails, and signaling apparatuses in addition to service providers including caterers and maintenance contractors (Carter & Rogers, 2008). The country's overall economic growth is aided by the multiplier impact of jobs associated with the railroad.

Further, it is impossible to overestimate the importance of railroads in fostering regional connectedness and prosperity. Railways serve as a means of facilitating the movement of people, commodities, and services between underdeveloped and rural areas and major economic hubs. This promotes inclusive development and reduces regional inequities. To open up new markets and integrate these regions into the national economy, railway lines had to be extended into previously unreachable places.

Additionally, the growth of Indian tourism is greatly aided by the railroads. The expansion of both domestic and foreign tourism has been facilitated by scenic railway lines, historic trains, and enhanced connections to tourist attractions. As a result, the tourist industry has expanded job prospects and brought in more revenue for the surrounding towns.

In addition to its economic achievements, the Indian Railways is essential for improving social cohesion and national unification. The railroads bring people from different areas, cultures, and socioeconomic backgrounds together by offering accessible and reasonably priced modes of transit. In addition to bridging social and economic gaps, this connectedness strengthens the feeling of national cohesion.

Because of the railway network's wide coverage across the nation, even the most isolated and underprivileged areas are guaranteed access to opportunities and vital services. People can now access jobs, healthcare, and education throughout the nation thanks in large part to the railroads, which have also played a key role in fostering social mobility. This has aided in India's general socioeconomic growth and strengthened the position of the railroads as a vital pillar of the country's infrastructure.

The importance of railroads in advancing environmental sustainability has come to light more and more in recent years (Chopra, 2019). Among the most energy-efficient forms of transportation is rail, which emits much less greenhouse gas per passenger or ton-kilometre than both air and road travel. As part of its commitment to lowering its carbon footprint and assisting India in meeting its climate objectives, Indian Railways is electrifying its entire network of trains and using renewable energy sources.

The railroad industry has adopted several green initiatives as a result of the government's emphasis on sustainable development. These include putting up solar panels at train stations, using bio-toilets on board, and encouraging the adoption of energy-efficient techniques while running trains. The railway industry is leading by example in terms of sustainability, not just by lessening their environmental effect but also by adopting sustainable practices.

The Indian Railways are essential to the nation's economy because they facilitate trade and commerce, encourage industrial expansion, provide jobs, assist regional development, strengthen national integration, and support environmental sustainability. The railroads' significance to India's economic and social growth is anticipated to become even more as they modernize and grow.

1.8 Intersection of SCM and Rail Transport

To improve the efficacy and efficiency of supply chains, rail transportation must be included in a larger framework for supply chain management. Compared to other forms of transportation, rail transit has several benefits, such as being more affordable, dependable, and able to manage big loads of cargo. However, there are also drawbacks to using rail transportation in SCM (Carter & Rogers, 2008). These include operational difficulties like scheduling and coordinating with other forms of transportation, as well as infrastructure-related problems like the availability and state of rail lines.

Comparatively, because of its reduced environmental impact and cost-effectiveness, rail transportation is still the favoured option for long-distance and bulk commodity delivery, even if air and road transportation also provide flexibility and speed (Christopher, 2000). A detailed examination of these trade-offs, as well as the unique needs of various industries and sectors, is necessary to comprehend the function of rail transport in SCM.

1.9 Major Role of SCM in Rail Transport

Although it offers a dependable, economical, and effective means of transportation for the flow of products, rail transport is essential to supply chain management (SCM). Rail transport plays a crucial role in the wider logistics network, making a substantial contribution to several facets of supply chain management (SCM) such as inventory control, distribution efficiency, and overall supply chain integration.

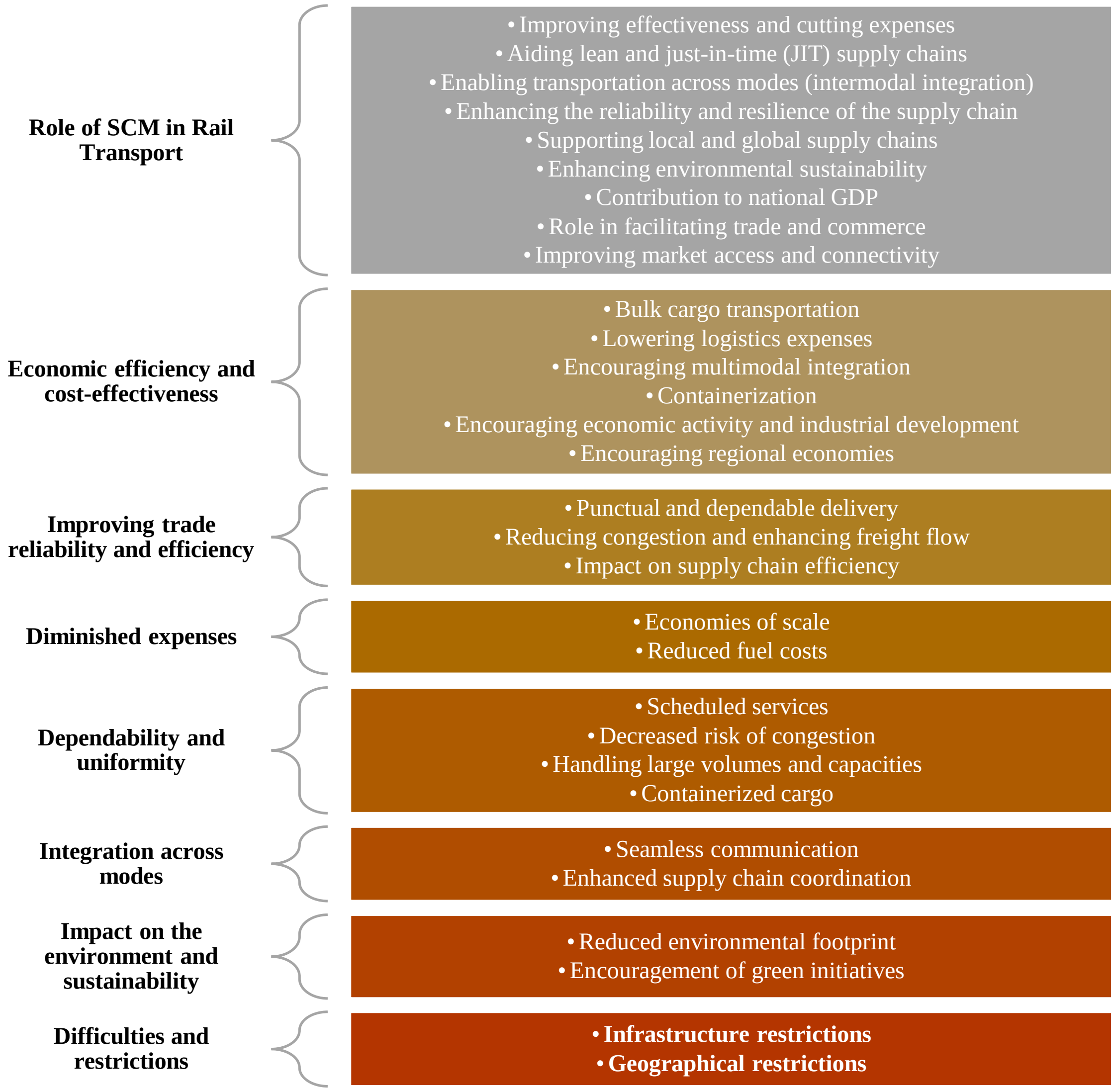

Figure 1.1: Role of Supply Chain Management

1.9.1 Role of SCM in rail transport

i. Improving effectiveness and cutting expenses

Rail transportation has helped in trading large quantities of commodities which can be moved across vast distances with great efficiency. The ability of trains to carry large quantities of intermediate and final commodities and raw materials lowers the cost of transportation per unit. For businesses that deal with bulk commodities like coal, iron ore, and agricultural products—where economies of scale are essential to sustaining competitive pricing—this efficiency is especially advantageous.

Many variables contribute to rail transit's cost-effectiveness, such as its capacity to carry huge loads in a single trip and its reduced fuel costs as compared to road transport. Companies looking to streamline their supply networks and lower overall logistics costs (Christopher, 2023). Businesses may save a lot of money by including rail transportation in their logistics plans. These savings can then be reinvested in other parts of the company or transferred to consumers at cheaper costs.

ii. Aiding lean and just-in-time (JIT) supply chains

Just-in-time (JIT) and lean supply chain techniques are supported by the incorporation of rail transportation into supply chain management. To decrease inventory levels and save waste, JIT demands exact scheduling for product delivery. Because of its regular services and dependability, rail transportation offers consistent and prompt delivery, which is in line with JIT principles. Railroads provide dependable and uniform timetables that assist businesses in aligning their supply chains and maintaining ideal stock levels (Flynn *et al*., 2009). Regular and large-scale shipments by rail may help businesses cut down on the need for huge stockpiles, simplify processes, and react more quickly to fluctuations in demand. This will be especially helpful to industries that rely on regular and consistent supplies to sustain effective manufacturing procedures.

iii. Enabling Transportation Across Modes

When moving commodities from one place to another utilizing a variety of modes of transportation, the process known as intermodal transportation is critical to rail transport. Road, sea, and air transportation are all frequently part of a larger multimodal logistics network that includes railroads. By combining the advantages of each mode of transportation, rail integration with other modes helps to maximize product flow.

For instance, rail travel is often used to convey cargo between ports and interior locations, when road transport is added for the last delivery leg (Chen & Paulraj, 2004). This multimodal strategy boosts the supply chain's flexibility and efficiency and lowers transportation costs. Road transport addresses the challenges of last-mile delivery, whereas rail transport is particularly useful for long-distance sections.

Intermodal logistics have been made easier by the use of containerization in rail transport, which permits the simple movement of products between rail and other modes of transportation without the need for extra handling. In addition to lowering the possibility of delays and damage during transportation, this seamless transition helps the supply chain run more smoothly.

iv. Enhancing the reliability and resilience of the supply chain

Because rail transportation is a steady and dependable form of transportation, it enhances supply networks' resilience and dependability. Compared to road transportation, trains are less impacted by weather-related delays and traffic congestion, which improves delivery consistency (Rodrigue *et al*., 2013). This dependability is essential for meeting client expectations and maintaining a seamless supply chain.

Its capacity to manage heavy loads during peak hours or supply chain interruptions is another example of rail transportation's resilience. During times of crisis, railways may provide a steady transportation alternative by absorbing variations in demand. In the event of unforeseen difficulties, this skill aids businesses in managing supply chain risks and preserving business continuity.

v. Supporting local and global supply chains

Because it facilitates commerce and improves connectivity, rail transportation is essential to regional and global supply networks. Railways enable the effective flow of commodities within a certain geographic area by connecting industrial hubs, ports, and distribution centers in regional supply chains. This connection promotes local businesses and aids in the integration of regional economies. Rail transportation is essential to global supply chain networks and international commerce (Christopher, 2023). The growth of global rail corridors like the China-Europe Railway Express, for example, emphasizes the importance of railroads in promoting cross-border commerce and tying together disparate geographical areas. Railways support the expansion of global supply chains by offering a dependable and affordable means of transportation. This promotes commerce and economic integration on a worldwide scale.

vi. Enhancing environmental sustainability

When it comes to ecology, rail transit is acknowledged as superior to other forms of transportation. Trains are a more environmentally friendly means of transporting products than air or road transport because they emit fewer greenhouse gases per passenger or ton-kilometer. Rail transportation's environmental performance is further improved using renewable energy sources and electrification further improves rail transportation's environmental performance (Srivastava, 2007).

The overall sustainability of logistics operations may be improved by integrating rail transportation into supply chain management. Railroads support the larger objectives of environmental stewardship and corporate social responsibility, which lower the carbon footprint of transportation-related operations and promote energy-efficient methods.

vii. Contribution to National GDP

As an effective, economical, and dependable form of transportation for product transfer of products, rail transport is essential to supply chain management (SCM). Rail transport plays a crucial role in the wider logistics network, making a substantial contribution to several facets of supply chain management (SCM) such as inventory control, distribution efficiency, and overall supply chain integration (Christopher *et al*., 2023).

Finally, it should be noted that rail transportation is essential to supply chain management because it promotes environmental sustainability, increases efficiency, lowers costs, supports JIT and lean strategies, facilitates intermodal transport, improves reliability and resilience, and supports both local and international supply chains. Businesses may improve their logistics, save costs, and successfully meet market needs by integrating them into supply chain processes (Sridhar, 2015).

viii. Role in Facilitating Trade and Commerce

Rail transport offers a dependable, economical, and efficient way to move products across borders and regions, it is essential in promoting trade and commerce. Because of its capacity to move heavy loads over great distances, it is an essential part of both local and international supply networks. This section examines how intermodal integration, connection, affordability, and support for economic activity are just a few of the ways that rail transportation fosters trade and commerce.

ix. Improving Market Access and Connectivity

Rail transportation improves domestic connection by connecting ports, key markets, and industrial hubs. This interconnectedness makes transportation of completed goods, intermediate commodities, and raw materials around the country easier. For example, India's vast rail network links rural areas to cities, facilitating the effective delivery of food and other commodities (Srivastava, 2007). Improved connectivity helps small businesses by giving them access to larger markets and boosting their competitive ability. International commerce facilitation: Rail transportation contributes significantly to the facilitation of cross-border commerce on an international level. Major ports and commerce centres are connected by railways, which facilitates the effective transfer of products between nations. One important economic route that connects China and Europe, for instance, is the China-Europe Railway Express, which makes it easier for commodities to move between Asia and Europe (Rodrigue, 2020). Railways facilitate international commerce and promote global supply chains by offering a dependable and affordable mode of transportation.

1.9.2 Economic efficiency and cost-effectiveness

i. Bulk Cargo Transportation

Rail transport is very economical when it comes to moving large quantities of goods like coal, iron ore, and farm produce. Trains' great capacity makes it possible to carry heavy loads of cargo quickly and efficiently, which lowers the cost of transportation per unit. Industries that rely on bulk commodities benefit from this cost-effectiveness because it lowers transportation costs and boosts overall economic efficiency.

ii. Lowering Logistics Expenses

For long-haul goods, rail transport is a more affordable option than air or road transport, which lowers logistical expenses for companies. This financial benefit is particularly beneficial for sectors of the economy that depend on large, frequent shipments of products. Reduced transportation costs may boost local product competitiveness on the international market and contribute to total cost reductions.

iii. Encouraging Multimodal Integration

Rail transportation is an essential part of intermodal transportation, which involves moving cargo from the point of origin to the point of destination using a variety of transportation methods. Intermodal logistics networks frequently rely on railroads as their backbone, since they link ports to interior locations and provide a reliable means of transportation over long distances. The efficient flow of commodities and improved supply chain performance are made possible by the combination of rail with road, sea, and air transportation (Lambert & Cooper, 2000).

iv. Containerization

By making it simple to move products between various means of transportation, the use of containers in rail transportation has completely changed logistics. Rail transport integration into global supply chains is facilitated by containerization, which lowers the risk of damage during transportation and facilitates handling. This adaptability promotes trade and business by making it easier for items to be moved effectively across different modes of transportation.

v. Encouraging economic activity and industrial development

Rail transportation promotes industrial growth by offering a dependable and affordable method of transferring raw materials and finished goods. Railways are essential for the transportation of commodities to and from production sites, distribution hubs, and marketplaces in sectors including industry, mining, and agriculture. By enabling industries to function effectively and competitively, this support for industrial operations promotes economic growth and development (Lambert & Cooper, 2000).

vi. Encouraging Regional Economies

By enhancing market accessibility and promoting commerce, the growth of rail infrastructure and services encourages regional economies. Enhanced economic activity, including job creation, company growth, and investment prospects, is advantageous for regions with well-developed rail networks. Enhanced rail connections promote overall economic development by facilitating the integration of regional economies into national and international markets (Cooper *et al*., 1997).

1.9.3 Improving trade reliability and efficiency

i. Punctual and Dependable Delivery

Rail transportation offers a dependable means of transportation with planned services and consistent journey durations. Businesses that rely on on-time delivery to satisfy customer requests and maintain effective supply chains require this dependability. By providing reliable and regular transportation, railways facilitate the smooth flow of products and improve commercial efficiency.

ii. Reducing Congestion and Enhancing Freight Flow

By offering a long-haul freight option, rail transportation helps to alleviate traffic congestion on road networks. In addition to improving total freight flow, this decrease in traffic congestion lowers the possibility of supply chain delays and interruptions. Rail transportation facilitates easier and more effective trade and business by reducing traffic on the roads. Rail transportation is essential for promoting trade and business because it improves trade efficiency, offers affordable transportation, supports intermodal integration, and fosters industrial expansion. Its contributions to both local and global commerce highlight how crucial it is to contemporary supply networks and economic growth (Frohlich & Westbrook, 2001).

iii. Impact on Supply Chain Efficiency

Rail transport offers an efficient way to move products across vast distances, which has a substantial influence on supply chain efficiency. It impacts many facets of supply chain management, such as integration, capacity, dependability, and cost reduction. This section examines the advantages and disadvantages of rail transportation in terms of improving supply chain efficiency in several dimensions.

1.9.4 Diminished expenses

i. Economies of Scale

By economies of scale, rail transportation provides significant cost benefits. When compared to road transport, trains have cheaper transportation costs per unit since they can carry enormous amounts of merchandise (Tang, 2006). Bulk commodities, including coal, minerals, and agricultural goods, benefit greatly from this efficiency. Rail transport lowers total supply chain expenditures and boosts profitability for businesses by lowering transportation costs.

ii. Reduced Fuel Costs

Generally speaking, rail transport uses less fuel than vehicle transport. According to (Coyle *et al*. 2012), trains use less fuel per ton-kilometre, which lowers fuel costs and has less environmental effect. This cost-effectiveness boosts the competitiveness of companies that depend on rail for transportation and adds to the total cost savings of the supply chain.

1.9.5 Dependability and Uniformity

i. Scheduled Services

The supply chain's consistent operation depends on the dependable and scheduled services that rail transport provides. Trains provide predictable travel times since they run on set timetables and predetermined itineraries. Because of its dependability, companies may lower inventory levels, increase supply chain planning efficiency, and lower the chance of interruptions.

ii. Decreased Risk of Congestion

Railroads are less prone to delays and traffic jams than are vehicles on the road. Because there is less chance of traffic jams, rail transportation is more dependable, and cargo arrives at its destination on schedule. Ensuring effective supply chain operations and satisfying customer needs are contingent upon dependable transportation.

iii. Handling large volumes and capacities

Rail transport is particularly effective at moving heavy loads of bulk freight. Trains are ideal for businesses that need to move large volumes of finished goods or raw materials because they can move a lot of cargo in a single trip. Because rail's great capacity allows large cargo to be moved with fewer trips, supply chain management is made more efficient.

iv. Containerized Cargo

The use of containerization increases capacity and efficiency in rail transportation. Containers make it easier to transport products across different modes of transportation, such as rail, road, and sea. This intermodal capacity lowers handling costs and optimizes the supply chain process. Rail transport supports standardized containers, which facilitates flexible and effective supply chain operations (Kong, 2023).

1.9.6 Integration across Modes

i. Seamless communication

Providing smooth communication between different forms of transportation, rail transport is an essential part of intermodal logistics networks. To facilitate the efficient transportation of products across various transport modes, railways often connect ports, distribution hubs, and interior destinations. By cutting down on transit times and improving transportation routes, this integration improves the overall efficiency of the supply chain.

ii. Enhanced Supply Chain Coordination

Rail operators, logistics companies, and other transportation stakeholders must collaborate to ensure seamless intermodal integration. Rail transport offers reliable, scheduled services that align with the timetables of other transportation modes, facilitating easier coordination. Improved collaboration enhances supply chain efficiency by ensuring the timely and smooth flow of goods.

1.9.7 Impact on the Environment and Sustainability

i. Reduced Environmental Footprint

Compared to air and road transportation, rail transportation often has a reduced carbon footprint because of its lower energy and greenhouse gas emissions per kilometre. Rail transportation's lower environmental effect helps to achieve sustainability objectives and makes the supply chain more sustainable. Businesses that place a high priority on environmental responsibility reap the benefits of rail transportation's favourable effects on their overall sustainability initiatives.

ii. **Encouragement of Green Initiatives**

The rail industry's investments in green technology and infrastructure further improve sustainability. The use of renewable energy sources and electrification of rail networks, for example, help to reduce the carbon footprint of rail transportation. By promoting green initiatives, rail transportation improves supply chain efficiency and aligns with wider sustainability objectives.

1.9.8 Difficulties and Restrictions

i. Infrastructure Restrictions

Although rail transportation has advantages, there are infrastructure-related problems. Supply chain operations may be disrupted, and rail transport efficiency may be affected by aging infrastructure, capacity limitations, and maintenance issues. To address these issues, modernization and infrastructure upgrades must be funded.

ii. Geographical Restrictions

The availability of rail networks and connectivity to isolated locations are examples of geographical considerations that restrict rail travel. Businesses may have difficulties obtaining rail transportation and incorporating it into their supply chains in areas with inadequate rail infrastructure. Maximizing the advantages of rail transportation requires overcoming these geographic constraints.

The cost savings, dependability, high capacity, intermodal integration, and environmental advantages of rail transportation have a substantial influence on supply chain efficiency. Despite obstacles to infrastructure and geographic constraints, its benefits in augmenting supply chain functions make it an essential constituent of contemporary logistics and supply chain administration (Gunasekaran *et al*., 2004).

1.10 Research Problem and Objectives

1.10.1 Research Problem

This thesis addresses the key challenges and opportunities in implementing effective supply chain management (SCM) practices within the Indian rail transport sector. The study aims to assess the current state of SCM in Indian Railways, identify major barriers to its optimization, and propose strategic solutions to improve the efficiency and effectiveness of SCM in this sector.

The research classifies various issues related to critical success factors in enhancing the performance of Indian Railways' supply chain. It also evaluates factors influencing service quality and identifies the critical success factors necessary for effective supply chain management. Efficient SCM in any organization relies heavily on the quality of its transportation infrastructure, both internally and externally. Indian Railways, the world's largest government-owned railway system, plays a crucial role as a supply chain partner to many service and manufacturing organizations across India.

The study concludes that road transport poses significant competition to Indian Railways in both freight and passenger services. Punctuality and safety are critical factors that influence customer and passenger preferences when choosing a mode of transport. Through the use of methodologies such as AHP (Analytic Hierarchy Process), ANP (Analytic Network Process), and ISM (Interpretive Structural Modeling), the research highlights the importance of these factors. The findings also emphasize the need for technological advancements to prevent derailments, the elimination of unmanned level crossings, and the reduction of accidents caused by human error.

1.10.2 The specific research questions that guide this study are:

1. What are the Supply Chain Issues in Rail Transport?
2. What are the major challenges in implementing effective SCM practices in Indian rail transport?
3. How is the Supply Chain Performance of Rail Transport?
4. What factors affect the performance of Supply Chain Management in Rail Transport?

1.10.3 The objectives of this study are to:

1. To study the Supply Chain Issues in Rail Transport
2. To study the barriers in Supply Chain Management in Rail Transport
3. To analyze the Supply Chain Management in Rail Transport
4. To study the Supply Chain Performance of Rail Transport

1.11 Structure of the Thesis

This thesis is organized into six chapters, starting with the introduction. Chapter two presents a comprehensive literature review on supply chain management (SCM) in rail transport, emphasizing relevant studies and theoretical frameworks. Chapter Three details the research methodology, including the research design, data collection methods, and analytical approaches used. Chapter Four explains the issues faced in supply chain in Indian railway and Chapter Five explains the barriers faced in supply chain in Indian Rail transport followed by chapter six exhibits the supply chain performance in Indian rail transport and Chapter Seven outlines the study's findings with key insights, policy recommendations, and suggestions for future research.

1.12 Conclusions

In this chapter, an overview of the importance of supply chain management in the context of rail transport in India has been presented. The significance of SCM in enhancing the efficiency of rail transport and its critical role in supporting the national economy has been highlighted. The chapter has further outlined the key challenges facing SCM in Indian rail transport and set the stage for the detailed analysis that follows in the subsequent chapters of this thesis. In next chapter Literature Review related to Indian Railway Transport Supply Chain Management is presented.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introduction

Indian Railways is the fourth-largest railway network in the world and the third-largest organization under single management. It contributes to the country's transportation needs as well as economic prosperity (Ketchen Jr. David, 2007). In the age of globalization, as an absolute necessity, a particular product or service should be delivered on time to end consumers at the lowest possible cost. For a product or service, the logistics and transportation costs are included in the total cost. However, despite substantial increases in shipment and passenger traffic, the market share of the Indian Railway has declined over the years compared to road transport.

The implementation of a robust supply chain management (SCM) system is required in order to address various issues related to the efficient flow of various goods, services, and information in the Indian Railway system. Because of the rising pace of urbanization, there is a growing demand for transportation, particularly in the railway industry. Passengers are received and processed at the railway station in this sector. When choosing a mode of transportation, a customer or passenger prioritizes punctuality and safety (Bhardwaj & Jawalkar, 2015.). The optimal design of the supply chain of Indian Railways is becoming a crucial topic for supply chain management scholars and practitioners (Cai, 2009). The need to regard the Indian railway system as an integrated system, and creating models and methodologies for optimizing supply chain priority has become a tough problem for the Indian railway system. The integrated system, financial behavior, and management viewpoint are all being reevaluated by Indian Railways to increase the efficiency and effectiveness of the system.

The lack of IT enablement in the material supply leads to an increase in the lead time, out-of-stock, and inventory problems and results in a loss of responsiveness and effectiveness of the supply chain (Sharma, 2016). By reviewing its internal operations, Indian Railways is trying to improve the efficiency and effectiveness of its internal operations, including servicing, warehousing, materials management, and distribution (Olsson, 2004). The issues in supplier selection in public procurement include limited order quantity, including the number of suppliers to be chosen, the minimum order quantity, etc. (Tripathi & Tanksale, 2023). The service quality at the railway station, such as cleanliness, safety, food, lodging, etc., improves the performance of the system and enables IR station managers, IR administration and policymakers to govern the IR system to the global standards with proper evaluation and prioritization (Sharma, 2018). Additionally, the performance of the IR was also varied in different railway zones. The southern IR zones' performance was better than that of the northern IR zones. Southern Railways has led the way in modernization and technology and continues to do so. It is renowned for its reliability, wide network, and security. It benefits from the region's many socioeconomic, environmental, and political advantages (Jose, 2023). The transportation industries like IR should adopt sustainable practices to tackle environmental, social, and economic issues (Gandhi & Kant, 2023). Economic factors were often preferred over social and ecological factors in railway projects to accomplish sustainability. A thorough understanding of the sustainability and challenges facing the goods railway industry enables managers and decision-makers to make the best plans and use their resources to improve sustainability at both the micro and macro levels and to break down supply-chain bottlenecks (Garg, 2020). In the face of a changing climate, the energy use and carbon emissions of railway transport are evident. The demand for monitoring systems continues to grow due to the higher requirements for safety and dependability brought on by faster railway travel. Seeking energy harvesting for self-powered monitoring or other track-side electrical systems is a sustainable way to lower operation and maintenance costs in situations where there isn't affordable access to electrical power sources (Zuo, 2022). Additionally, waste management and the of plastic trash are serious environmental challenges. Throwaway culture and the absence of a waste management system are the primary causes of environmental difficulties involving plastic trash in the first place. It is due to the habits of individuals as well as a lack of infrastructure for the proper disposal of solid waste. Problems have been detected in the collection, transportation, and disposal systems and measurable plastic garbage at railway stations. Inadequate resources, inadequate technology, management indifference, and low system efficiency all contribute to the failure of the system to provide fruitful results. It is due to the habits of individuals as well as a lack of infrastructure for the proper disposal of solid waste. Problems have been detected in the collection, transportation, and disposal systems, as well as measurable plastic garbage at railway stations. Despite their best efforts, the Indian Railways haven't been able to solve problems with their supply chain management. Therefore, the study seeks to look at the Indian Railways (IR) supply chain.

2.2 Past Study on Barriers Rail Transport in Supply Chain Management

Supply chain management for the Indian Railways is a critical aspect of ensuring the smooth operation of one of the largest rail networks in the world. Supply chain management is a complex and multifaceted task that involves various stakeholders, including government agencies, private sector partners, and logistics experts. It plays a crucial role in supporting the transportation of goods and passengers across the country efficiently and reliably. For the supply chain to be internally sustainable, it has to be able to self-correct depending on external inputs. According to the World Resources Institute, managers will promote the integration and coordination of practices across the supply chain as firms that make up a supply chain become more conscious of consumer needs for goods and services that do not cause environmental harm (Bhanot, 2004). Environmental sustainability and global supply chain management (GSCM) may give supply networks an edge over their competitors. Research in this area focuses on supply chain management's "boundary-spanning" function in implementing environmental measures in the supply chain. Supply chain partners must consider transaction costs while striving to increase environmental sustainability in the supply chain (Rahimi, 2020). The development of green practices is also driven by environmental law and regulation, in addition to the demands of customers. There is little unanimity on the impact of environmental regulation on company competitiveness. In regards, reverse logistics is an important initiative to maintain the environmental sustainability within the supply chain system. By managing the end-of-life (EOL) of products, reverse logistics and product take-back initiatives can help to lessen environmental damage (Bouzon, 2018). Additionally, Train Control Information Systems (TCIS) are highly developed systems that have a significant positive impact on railway sustainability. It mostly includes train interlocking system, train management and their subsystem. Additionally, cost of equipment, installation, maintenance and safety are also important factors in enhancing the performance and sustainability of the railway system (Krmac & Djordjević, 2017). Consumers may get goods and services via an organization's supply chain (Ranjan, 2016). It establishes a link between the point of origin and the point of destination regarding materials flow. The raw material supply chain comprises the storage, loading, and shipping to the end consumer of raw materials. Thus, transportation has become an integral part of the supply chain and is one of the most crucial building blocks in a country's economic growth (Vidoni, 2020). Indicators of a nation's transportation system efficiency include how quickly and easily people and goods can move around a country. Many means of transportation are used to offer freight service, including railroads, highway systems, planes, and ships. Figure 2.1 depicts the supply chain management for the Indian railway system, demonstrating specific flows' involvement. To improve performance, Indian Railways uses Lean Supply Chain techniques that include supply chain features, integration, and customer service. According to new research, supply chain management may be structurally or situationally dependent. Because of this, there may be a wide range of supply chain management approaches in various nations.

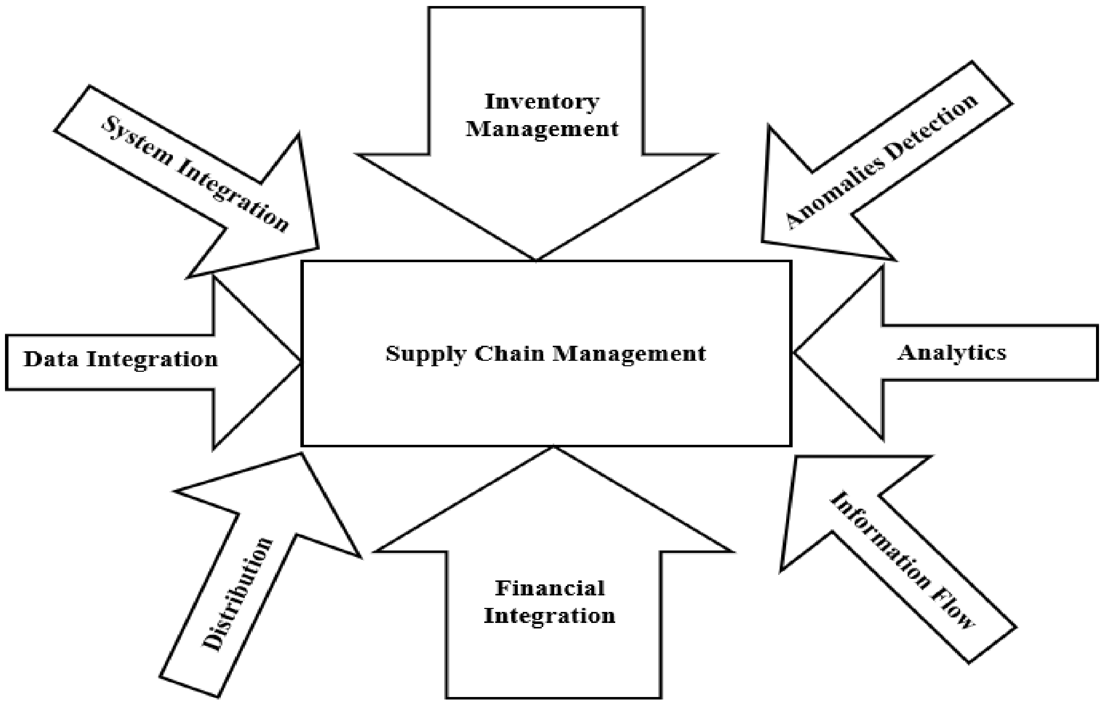

Figure 2.1: Supply Chain Management

2.3 Management of the Supply Chain and the Railway System

The transportation and freight moving firm Indian Railways (IR) is a government-owned company overseen by the Ministry of Railways. The Railway Board is India's highest decision-making body, and its chairman is a cabinet minister (Rosberg, 2021). The Railway Board is responsible for policy formation, goal setting, performance monitoring, cadre planning, and the central purchasing agency's centralized procurement of high-value products such as whole rolling stock. Supply chains connect the supply of raw materials to the ultimate delivery of a product or service to a client by forming an interconnected network of businesses. Purchasing raw goods, storing them, loading them, and shipping them to the final consumer are all part of the supply chain. Transportation is now an essential aspect of the supply chain (Hassan, 2021). The development of a country's transportation infrastructure is one of its most significant building components. When a nation's transportation system performs well, it reflects on how easy it is to move throughout the country and convey commodities from one place to another. Various types of transportation are employed for freight service, such as railways, highways and rivers, and airplanes. Rail transportation board members in charge of mechanical engineering and material management are responsible for rolling stock, such as wagons, coaches, diesel locomotives, etc. (Cullinane, 2017). Performance has grown into a supply chain management role and is now self-contained. An action's efficiency and effectiveness may be quantified using performance measurements. Decisions and actions may be taken based on the information provided by performance measuring systems. Defining strategic goals, measuring performance, and planning for the future are all influenced by this tool. Supply chain failures are often due to a lack of a measuring system. So the true problem is to generate a performance that is appropriate. So that the company's performance and competitiveness may be improved (Agrawal, 2020). The key performance indicators of IR are compared to those of a typical automobile firm to better understand and assess how effectively the inbound supply chain functions.

To enhance the overall profitability of an SC, SCM entails managing the flows between and among its stages (Chopra *et al*., 2004). SCM is organizing all activities associated with purchasing, sourcing, conversion, and logistics management, according to the Association of SCMP. Most importantly, there is collaboration and coordination with suppliers, including customers, intermediaries, suppliers, and outside service providers. Stated differently, supply chain management (SCM) unifies demand and supply control inside and across businesses.

Supply chain management (SCM) is the integration of vital company procedures from the end user to original suppliers, offering products, services, and expertise that provide value for consumers and other stakeholders, according to the Global Supply Chain

Forum (GSCF). Or, to put it another way, supply chain management (SCM) is the act of integrating essential business processes to provide value for stakeholders and customers (Lambert, 2008).

Essentially, supply chain management (SCM) involves applying a range of managerial techniques to effectively integrate the operations of producers, distributors, retailers, warehouses, transporters, and vendors so that the goods that are produced are sent to the appropriate buyers in the appropriate amounts and at the appropriate times while imposing the lowest possible total expenses across the entire SC. SCM is becoming a more popular business technique that can integrate every aspect of the supply chain and give a company a long-term competitive edge.

Table 2.1: Common parameters in supply chain management

Factor ⇒ **Author ⇓**	Availability	Quality of railway service	Reliability	Integration System	anagement	Financial
Mentzer J. T *et al.* (2001)	+	+	+	+	+	+
Olsson *et al.* (2004)	+	+		+	+	+
Trkman P. *et al.* (2006)	+	+		+	+	+
Ketchen Jr. *et al.* (2007)	+		+	+	+	+
Cai J., *et al.* (2009)	+	+	+	+	+	+
Annual Report (2012)	+	+	+	+	+	+
Bhanot, N. *et al.* (2014)	+	+	+	+	+	+
Bhanot, N. *et al.* (2014)	+	+		+	+	+
Ranjan, R., *et al.* (2016)		+	+	+	+	+
Awasthi, A., Sayyadi *et al.*(2018)	+	+	+	+	+	
Budget *et al.* (2019-20)	+	+	+	+	+	+
Das, A.K. *et al.* (2019)	+	+	+		+	+
Hassan, M.M. *et al.* (2021)	+		+	+	+	+
Khan, A. and Gulati, R. (2021)	+	+	+	+	+	

2.4 Importance of Supply Chain Management in Rail Transport

In the rail transport sector, SCM is essential to flow supplies and goods from producers to customers smoothly. SCM aids in the optimization of several operational elements of rail transportation, such as resource allocation, scheduling, and routing. As a result of this optimization, rail networks are used more effectively, cutting expenses and transit times. A well-functioning supply chain guarantees prompt delivery of goods, satisfying the needs and expectations of customers. On-time and dependable rail services build long-term customer connections by improving customer satisfaction.

Effective supply chain management reduces transport, handling, and inventory holding expenses. Rail firms can reduce operating costs by streamlining these procedures and offering consumers more competitive pricing. The study revealed a strong positive association, demonstrating that supply chain performance and practices influence organizational performance, particularly in efficiently delivering high-quality service (Mathur, 2018). Supply chain management requires flexibility, especially in volatile markets. Interpretive structural modeling provides a systematic way to handle complexity by determining the relationships and categories of elements affecting agility.

Supply chain managers can use this information to inform their strategic planning, improving supply chain agility and successfully satisfying customer needs (Ashish Agarwal, *et al,* 2007). An essential component of the country's supply network is the railroad. When shipping freight by rail, costs are frequently lower, logistics are more effective, and the environment is protected. It involves using cars that operate on rails or railroads for transportation purposes. It is a highly important and widely used method of transportation for both short and long-distance freight and passenger travel, known for its affordability. It involves several procedures, including acquiring raw materials, shipping them to production locations, using them to make things, delivering the finished product to the client, and even maintaining track of the whereabouts of the sold items.

SCM helps to maintain optimal inventory levels. Bulk shipments are a common feature of rail transport, and efficient inventory management guarantees balanced stock levels, preventing overstocking. An efficient supply chain allows for resource and route optimization, which lowers wasteful transportation and, as a result, the carbon footprint. Rail transit is naturally more environmentally benign than other modes, and SCM further increases these advantages. Collaboration between different stakeholders, including manufacturers, distributors, rail operators, and regulatory bodies, is facilitated via supply chain management (SCM). With a well-organized administration, rail transportation can quickly adjust to changes, guaranteeing minimal service interruptions.

Global trade heavily relies on rail transportation. SCM in rail transportation makes cross-border movement of commodities easier by handling taxes, international compliance requirements, and customs rules. Ensuring the smooth and efficient delivery of final goods to customers is vital to transportation management. Transportation is one of the rare instances in supply chain operations where businesses communicate directly with customers. Ensuring timely and reliable delivery while proactively addressing potential obstacles can enhance customer satisfaction and establish your company as a reliable and trustworthy organization. Because the Indian vehicle industry has a substantial market share in the country's manufacturing sector, this research suggests a framework for it. It fills a gap in the existing literature, which often ignores the broader context of Industry 4.0 and lacks empirical validation. To close this gap, this study offers an extensive perspective and verified data (Krishnan, 2021). Maintaining ideal inventory levels is aided by SCM.

Bulk shipments are a common feature of rail transport, and efficient inventory management guarantees balanced stock levels, preventing overstocking or stock outs. An efficient supply chain allows for resource and route optimization, which lowers wasteful transportation and, as a result, the carbon footprint. Rail transit is naturally more environmentally benign than other modes, and SCM further increases these advantages. Collaboration between different stakeholders, including manufacturers, distributors, rail operators, and regulatory bodies, is facilitated via supply chain management (SCM). Good coordination minimizes delays and interruptions by ensuring efficient information flow and decision-making procedures. Analysing market trends and demand patterns is part of supply chain management. Rail firms may arrange their services accordingly and guarantee that the right resources are available when and where they are needed with the help of accurate demand forecasts.

Reacting to unanticipated events, such as natural catastrophes or supply chain disruptions, requires an agile supply network. Rail transportation can quickly adjust to changes with efficient administration, guaranteeing minimal service interruptions. Global trade heavily relies on rail transportation. SCM in rail transportation makes cross-border movement of commodities easier by handling taxes, international compliance requirements, and customs rules. Supply chain management is critical to the rail industry's ability to maximize productivity, improve customer happiness, cut expenses, advance sustainability, encourage teamwork, facilitate efficient planning, assure flexibility, and support international trade. It is the foundation of effective and dependable train services and substantially contributes to nations' and regions' general social and economic advancement.

2.5 Challenges Faced by Rail Transport

Indian railways have attracted attention from suppliers, business experts, and policymakers due to their focus on transportation logistics. Recent studies in the sector highlight a similar level of interest in different strategies among suppliers in rail transport. However, the rail transport sector needs more information regarding supply chains. Access to publications in the databases is limited, creating a barrier for suppliers and the rail transport supply chain. Finding a suitable literature review for the project is of utmost importance. To gather relevant literature articles, we incorporated search phrases related to barriers in rail transport and the integration of Industry 4.0 into supply chain management. To successfully handle sustainability concerns, managers and industry experts may benefit from the insights provided by this research (Vishwakarma *et al*., 2022).

In the context of rail transportation, we also concentrated on the idea of an environmentally friendly supply chain. These articles are grouped around the search phrases that were previously mentioned. The management of supply chains in rail transportation has several challenges and issues, which may have an impact on the efficacy, reliability, and efficiency of the system. SCM in rail transportation faces the following major challenges.

2.5.1 Infrastructure Barriers in Supply Chain Management

These major obstacles directly affect the efficacy and competence of the SC process, posing a challenge to SC managers. When it comes to train transportation, these obstacles might be especially intimidating. It can be complicated to adopt and apply sustainability ideas at a larger scale in manufacturing and operations businesses; obstacles are often involved. A tiny handful of writers have made an effort to look into the challenges facing sustainable innovation. Research has shown that financial mobilization strategies, including monetary collaboration between public and private institutions, the accessibility of financial instruments, along legislative and regulatory encouragement for innovations, can help policymakers, elected officials, and sustainable policies address issues overcoming the economic, technological, and regulatory obstacles that stand in the way of sustainable innovations. The effect of financial barriers on sustainable innovations was examined by (Cecere *et al.*, 2020) in a different study. They studied the impact of internal and external funding sources on inventions and public funding. According to the findings, one of the biggest obstacles to sustainability innovation is a need for more internal finance. Another is a need for more money from public sources, such as government agencies. However, the absence of funds from other outside sources has little effect on initiatives related to sustainability and innovation. To find the obstacles to environmentally friendly and sustainable innovation (de Jesus Pacheco *et al.*, 2018) comprehensively evaluated the literature. A few major challenges were noted by them, including a deficiency of skilled staff and administrative ignorance of the benefits of sustainable technologies to put them into practice, a shortage of consumer acceptance and knowledge of maintainable products, a lack of funding for related R&D, and the view of sustainable innovation as an expense rather than an investment for the future. Their study on the route to an economy that is circular through sustainability innovation (de Jesus & Mendonça, 2018) looked at the barriers to this transition to sustainability.

The obstacles were divided into two main groups: "Hard" and "Soft" barriers. Hard barriers include: Implementing innovative environmental projects with the incorrect technologies.

Creating a disconnect between technology design and adoption. And not having enough training on sustainability.

The "Soft" barriers include high initial cost, insufficient and deficient information for making decisions and conducting commercial activities, a lack of information and substantial financial support for sustainability initiatives, an inappropriate framework for carrying out sustainability, and consumer resistance to environmentally responsible and innovative products. With an emphasis on specific Australian locations, (Greenland *et al.*, 2018) studied the adoption of sustainable innovations for drip irrigation and food production. They identified the complex relationships that exist between external and internal difficulties. Not having government assistance was one of the main obstacles, along with the expenses of sustainability innovation and the characteristics of users to assess whether sustainability innovation was appropriate for them. (Gupta and Barua, 2018) looked at small and medium-sized businesses' challenges regarding sustainable and green innovation.

They delineated seven primary categories of barriers, which include technological, managerial, Financial, cost-effective, resource-related, and partnership-related obstacles. The study revealed that the primary obstacles impeding sustainable and environmentally conscious innovation in firms are related to technology and resources and financial and economic issues. The survey conducted by (Kiefer *et al*., 2019) uncovered an intriguing discovery regarding the hurdles to innovation for sustainability: most research focuses on external barriers, whereas internal constraints are frequently given less weight than external barriers. (Arranz *et al*., 2019) conducted a research investigation on Spanish organizations, and the study's main conclusion was that organizations need help to embrace sustainable innovation strategies due to their complexity. The market's reluctance to embrace sustainable innovation and the unpredictability of the procedures involved in innovation are two more significant obstacles. Researchers also discovered that government financing, partnerships, and information sources on eco-friendly technologies can aid in promoting the adoption of sustainable innovation in businesses.

2.5.2 Operational Difficulties in Supply Chain Administration

The horizontal view of a cohesive supply chain leads to an improvement in operational competency. An organization's capacity to provide just-in-time and inventory management services, which facilitate quick product availability for clients, is one way logistics services improve operational competency. Additionally, to meet demand, it enables quick adaptation to the network of distribution (Derwik, 2020). Design, expenses, and delivery are a few additional operational competencies. Controlling and reducing costs is a key component of the cost competency. An organization's capacity to develop new products and alter existing ones is known as its design competency. Offering items with faster delivery times is the definition of delivery expertise. The research's conclusions are consistent with those of other studies. According to the research, Supply chain procedures directly impact competitive advantage. The need for

HSSC stakeholders to prioritize these issues is emphasized. To improve BCT acceptance in HSSC, future research areas, and practical implications are also provided (Vishwakarma, 2023).

SCI and operational capabilities are related, according to network theory. The network viewpoint focuses on how various organization stakeholders connect. Coordination plans and initiatives improve individual firms' capacities, resources, and skills. Through internal decision-making and activity between the company and its external partners, firms could become more competitive (Bedi *et al*., 2018). Furthermore, according to RBV, a company eventually acquires operational capability a non-replaceable, path-dependent, and unique skill. Building, and maintaining a competitive advantage is made easier for a company with operational capacity. A company must have close, cooperative relationships with its suppliers to implement SCM. As pointed out, the firm's long-term strategic alliances impact the activities' domain. It was also mentioned that integrating suppliers can offer a novel way to advance internal operating competencies. The capacity of a business to generate revenue and integrate its supply chain is favored by this strategic assignment. It also affects the manufacturer's ability to contend (Silva *et al*., 2020).

2.5.3 Regulatory and Compliance barriers in Supply Chain Management

Compliance with regulatory bodies in supply chain management (SCM) refers to following the rules, standards, and guidelines that govern the whole process of purchasing, producing, and delivering goods. It is composed of several components, such as environmental efforts, safety standards, and labor laws. Without a doubt, implementing and adhering to regulations is crucial for SCM. You can guarantee legal compliance and lessen the likelihood of penalties, enforcement actions, and reputational damage by doing this. In the end, it increases the overall efficacy and reliability of SCM procedures by promoting openness, accountability, and moral business conduct. It is also necessary for maintaining a trustworthy and secure work environment, managing supply chain security concerns, and guarding against theft, unauthorized access, and counterfeiting (Sallam *et al*., 2023).

Due to the possibility of standards being broken, supply chains that are longer and more complicated tend to be less traceable and so more vulnerable. The Waste In - Waste Out dilemma states that data saved in a database is only as good as its input, which may be the most difficult challenge. Physical objects and real-world stakeholders must thus be linked to distinct digital identities. Furthermore, these correlations must hold for the duration of the supply chain. At least currently, blockchain technology cannot offer a complete solution for securely and robustly connecting real-world things with virtual identities. No other kind of database can either. Two effective strategies to close this gap are incorporating IoT gadgets and using rewards based on tokens (Katsikouli *et al.*, 2021). Based on existing literature, there is limited information regarding implementing IT-enabled supply chain management. Implementing IT-enabled solutions has greatly improved the efficiency of the Indian rail supply chain, although there are still barriers to overcome along the way.

2.6 Identifying Barriers

The in-depth literature and consultation with Indian rail transport suppliers led to the identification and placement of ten barriers in Table 2.2.

2.6.1 Lack of Top Management Commitment

Building trust, fostering knowledge sharing, and synchronizing decisions are crucial for effective collaboration, which can lead to improved intermodal transportation and cost reduction. Collaboration is also essential to attain economies of scale (Elbert *et al.*, 2017). The study's distinctive contribution lies in studying the influence of various stakeholders in the intermodal freight industry, an area that has yet to receive much attention in previous research. The findings propose proactive measures for policymakers to tackle inhibitors of Indian railways and improve modal balance in emerging economies (Aalok Kumar *et al.*, 2020).

2.6.2 Inefficient information and technology system

More user-friendly software to enhance traceability and communication between railways and goods shippers (Woxenius *et al.*, 2013). This study provides recommendations for improving the quality of urban transport services, specifically focusing on rail transport and potential users. In this chapter examines the conventional business model in passenger transport and explores the integration of carrier internet services on e-business platforms, utilizing cutting-edge internet technologies. In this chapter highlights the importance of embracing innovative transaction models in the railway sector to meet the needs of service users in the digital age (Pavlovic *et al.*, 2021). Transportation of products between railroads and seaports necessitates additional processes and waiting times because many providers still depend on various systems of information. Insufficient access to relevant data greatly hampers the forecasting capabilities of individuals, leading to their struggles in adapting to shifts in intermodal transportation structures (Wang *et al*., 2017).

2.6.3 The disinclination of the support from distributors, retailers, and dealers

There is an additional barrier that exists in the Indian railway sector. When suppliers fail to meet their commitments or distributors and dealers do not provide adequate support, it can lead to a breakdown in trust between traders. Suppliers must ensure timely delivery of the consignment. An improved supplier relationship can result in enhanced product quality, on-time delivery, increased flexibility, and reduced product costs. Additionally, establishing a long-term partnership with all supply chain members can enhance overall performance (Vachon *et al*., 2006). A lack of support from suppliers can significantly impact the overall performance of the SC (Meena *et al*., 2013) & (Meena *et al*., 2014).

2.6.4 Lack of policy support for strategic/long-term contracting

Top management must prioritize strategic planning to stay competitive in the current business landscape. In addition, strategic planning plays a crucial role in achieving goals (Joshi *et al*., 2013). The study addresses the delicate matter of public procurement systems, offering valuable insights for policymakers. It promotes the integration of business management principles into public-sector practices. Ultimately, the chapter introduces a fresh conceptual framework to clarify the essential elements of managing the flow of goods and services within the public procurement environment, providing a ground-breaking contribution to the field (Gupta *et al*., 2015). Strategic planning involves developing innovative approaches for the company to enhance profitability in line with current market trends and customer demands. Unfortunately, Indian logistic companies are struggling to implement environmentally friendly freight practices due to a lack of support for strategic planning (Orji *et al*., 2019).

2.6.5 Lack of IT skilled / trained manpower in field units

This chapter aims to identify the obstacles that significantly impact the IT enablement of the SC. These barriers can be categorized as driving barriers and dependent barriers.

Doing so aims to provide management with valuable insights on how to systematically and effectively address these obstacles. This can be achieved through prioritization and developing appropriate strategies (Sharma, 2016). A diverse selection of environmentally friendly vehicles is ideal, efficient, and prioritizes environmental consciousness. Unfortunately, a lack of hybrid and IT-skilled engineers with technical (IT) management knowledge has hindered our progress in introducing advanced vehicles in the Indian freight logistics industry (Ehsani *et al*., 2018).

2.6.6 Lack of collaboration among supply chain partners

Ultimately, building trust, fostering knowledge sharing, and achieving decision synchronization among the various actors in the intermodal network is crucial for effective collaboration and maximizing the utilization of intermodal transport (Bergqvist *et al*., 2016). Horizontal collaboration by itself collapses short; what is truly effective is a vertical collaboration between shippers, rail operators, and logistics service providers (Monios *et al*., 2017). Efficient coordination of activities across various modes of transportation is essential (Bubnova *et al*., 2018).

2.6.7 Environmental Issues

This study passage highlights the significance of adopting a comprehensive approach to evaluating environmental impacts in transportation. It emphasizes the importance of decision-makers considering the complete life cycle of vehicles and infrastructure when formulating mitigation policies and strategies (Chester & Horvath, 2009). Insufficient understanding of the environmental impacts of railroad transport and the positive aspects of intermodal Indian rail transportation. Considering the environment is crucial for enhancing the long-term sustainability of the freight transportation system (Eng-Larsson *et al*., 2012). However, within the freight rail transportation system, shippers tend to prioritize cost over environmental impact when choosing a mode of transport. They have found that the cost of transportation has a greater influence on their decision-making process than non-monetary factors such as reliability, flexibility, and frequency (Arencibia *et al*., 2015).

2.6.8 Natural Disasters and Weather Conditions

This study proposes a thorough investigation into the difficulties of unusual weather and natural disasters on transport systems. The main objective is to comprehend the underlying mechanisms, analyze real-life examples, and suggest efficient prevention and control strategies, including policy measures (Huapu Lu *et al*., 2020). This study emphasizes the significance of acknowledging the dual role of transportation companies in climate change and the need for collaborative efforts to adopt sustainable practices and build resilience in the transportation sector (Julia Bettina Leicht *et al*., 2024). This study focuses on the difficulties of planning emergency transportation in disaster relief supply chains. It introduces a unique multi-objective fuzzy optimization method to tackle these difficulties. The proposed method focuses on enhancing the efficiency and effectiveness of emergency response efforts in the face of natural disasters (Zheng *et al*., 2013).

2.6.9 Security concerns

The importance of addressing security challenges in distribution chains and the necessity for thorough research to inform decision-making and improve the resilience of supply chains against different threats cannot be overstated (Urciuoli, 2010). The studies emphasize important areas of focus, obstacles, and potential resolutions discussed in the literature. These cover various aspects of security and privacy in railway systems, including technical, societal, regulatory, and moral issues (Pablo López-Aguilar *et al*., 2022). Modern railway systems face significant cyber-physical security risks, particularly with technologies like Balise. The suggested solutions, utilizing machine learning and fuzzy countermeasure systems, present promising possibilities for enhancing safety and resilience against cyber-attacks without requiring extensive measures (Abolfazl Falahati *et al*., 2021).

2.6.10 Lack of responsiveness

The significance of rail transport in managing supply chain operations is highlighted, addressing crucial concerns and considerations. It also provides strategies to effectively manage and enhance rail freight networks to meet the changing demands of global trade and logistics (Gholamizadeh *et al*., 2022). In addition, it is important to acknowledge the institutional challenges that may arise, as there are often business factors that can hinder the success of an intermodal transport service (Monios *et al*., 2017). The obstacles to intermodal transport vary based on the viewpoints of different actors. Society prioritizes sustainability, shippers prioritize business, and carriers prioritize production efficiency. However, the effectiveness of intermodal transport relies heavily on its effects on the logistics performance needed from the entire transport supply chain (Eng-Larsson *et al*., 2012). The flexibility and ability to meet the demands of supply chains, as well as the communication, collaboration, and information flow between different actors who may also be competing with each other in other orders, are crucial (Monios *et al*., 2017).

By highlighting the importance of IT-enabled SCM in rail transportation, the study's discussion above gives perspective. Following are the studies identifying the barriers listed below in Table 2.2.

Table 2.2: Barriers in SCM in Rail Transport

S. No	Barriers	References
B1	Lack of top management Commitment	Elbert *et al*., (2017); Monios, (2015); Aalok Kumar *et al*., (2020).
B2	Inefficient information and technology system	Pavlovic *et al*., (2021); Woxenius *et al*., (2013); Wang *et al*., (2017).
B3	The disinclination of the support from distributors, retailers, and dealers	Meena, P.L.*et al*., (2013);Meena, P.L.*et al*., (2014); Vachon *et al*.,(2006)
B4	Lack of policy support for strategic/long-term contracting	Gupta *et al*., (2015); Joshi *et al*., (2013); Orji *et al*., (2019).
B5	Lack of IT skilled / trained manpower in field units	Sharma, (2016); Ehsani *et al*., (2018).
B6	Lack of collaboration among supply chain partners	Bergqvist, R., (2016); Monios *et al*., (2017); Bubnova *et al*., (2018).
B7	Environmental Issues	Chester *et al*., (2009); Eng-Larsson *et al*., (2012); Arencibia *et al*., (2015).
B8	Natural Disasters and Weather Conditions	Huapu Lu *et al*., (2020); Zheng *et al*., (2013); Leicht *et al*., (2024).
B9	Security concerns	Urciuoli, (2010); Pablo López-Aguilar *et al*., (2022); Abolfazl Falahati *et al*., (2021).
B10	Lack of responsiveness	Gholamizadeh *et al*., (2022); Monios *et al*., (2017); Eng-Larsson *et al*., (2012).

2.7 Supply Chain Performance of Rail Transport

Supply chain management plays an important role in improving the efficiency and competitive spirit of businesses. Though supply chain management has been developed as an essential business philosophy and practice, there are several challenges as firms compete across boundaries. These challenges are harder in a global manufacturing environment where firms have a universal presence through mergers or consolidation. Current hard-hitting economic situations, increased competition, changing product characteristics, and uncertainty in demand, make it more challenging to manage such supply chains. Many companies run into problems because they fail to have proper supply chain strategies in place or fail to implement strategies that maximize both customer and shareholder interests.

Even though it's frequently mentioned, not much is known regarding senior management's involvement in supply chain management techniques. Thus, the goal of this essay is to investigate how senior management functions in two retail businesses that effectively take advantage of the advantages provided by SCM techniques. Two Swedish retail enterprises are investigated to provide an empirical foundation for the study. Interviews regarding the roles and priorities of the top management teams have been conducted. Four archetypes the planner, organizer, controller, and manager of supply chain for the future are introduced to characterize the findings of the top management function. The research study advances current theory by providing a more thorough explanation of top management's role in supply chain management (SCM) practices, or how SCM practices could be managed in reality. It also advances knowledge of what is required to implement more SCM practices in actual supply chains and businesses (Sandberg & Abrahamsson, 2010).

The major constructs affecting the supply chain performance are our top management commitment, supply chain collaboration, supply chain management rail transport, and supply chain performance. Below systematic literature is exhibited in Table 2.3:

Table 2.3: Constructs of the supply chain in rail transport and their literature sources

S. N.	Construct	Items	Item Name	References
1	Top Management Commitment (TMC)	TMC-1	Developing strong, long-term, collaborative relationships with suppliers	(Lee, H.L. 2004), (Swafford *et al*., 2006)
		TMC-2	Using intermediaries to develop fresh suppliers and logistics infrastructure.	(Gligor, D.M. *et al*., 2014), (Gligor *et al*., 2015).
		TMC-3	Freely exchanging information with suppliers and customers.	(Stevenson, M. *et al*., 2007), (Stevenson, M. *et al*., 2009)
		TMC-4	Having a clear customer and shareholder focus	(Srikantha *et al*., 2009).
		TMC-5	Supporting the acquisition and implementation of appropriate information systems	(Srikantha *et al*., 2009).
		TMC-6	Benchmarking and continual improvement	(Srikantha *et al*., 2009).
2	Supply Chain Collaboration (SCC)	SCC-1	Improve information sharing.	(Simatupang *et al*., 2005).
		SCC-2	Decision synchronisation	(Simatupang *et al*., 2005).
		SCC-3	Improve incentive alignment	(Simatupang, T.M. *et al*., 2004).
		SCC-4	Improves the supply chain configuration.	(Hudnurkar, M., *et al*., 2014), (Angerhofer, B. J., *et al*., 2006).
		SCC-5	Improve the enabling technology.	(Angerhofer, B. J., *et al*., 2006), (Lee, J., *et al*., 2011), (Crook, T. R., *et al*., 2008).
		SCC-6	Enhanced level of collaboration	(Angerhofer, B. J., *et al*., 2006), (Zacharia Z. G., 2009).

S. N.	Construct	Items	Item Name	References
3	Supply Chain Management Rail Transport (SCMRT)	SCMRT-1	Designs of specialized engineering related to the upgrading locomotive power supply systems	(Jäppinen, E., *et al.*, 2014); (Wanke, P., *et al.*, 2015); (Zuo, C., *et al.*, 2013).
		SCMRT-2	Enhance optimal systems at a reasonable cost and receiving the highest profit.	(Abbas, D., *et al.*, 2013); (Hendrickson, C., *et al.*, 2006); (Yuqian, L., & Siping, Q. 2010).
		SCMRT-3	Optimisation to achieve maximum energy and minimum consumption.	(Rao, S. S., 2019); (Antoniou, A., 2007); (Zang, Y., *et al.*, 2010).
		SCMRT-4	Introduction of mathematical algorithms for planning and scheduling	(Gholamizadeh, *et al.*, 2024); (Hajiaghaei-Keshteli, *et al.*, 2014); (Zinder, Y., *et al.*, 2016).
		SCMRT-5	Improvement of specialised approaches to the safety assessment of railway systems in a dynamic framework.	(Mohammadfam, I., *et al.*, 2020); (Zarei, E., *et al.*, 2013); (Park, T., *et al.*, 2013).
		SCMRT-6	Development of a specialized method for analyzing the performance errors of operators in digital rail control rooms.	(Mirzabeiki, V., *et al.*, 2012); (Narayanaswami, S., *et al.*, 2013); (Deng, Y. T., 2014).
4	Supply Chain Performance (SCP)	SCP-1	Improve service effectiveness for suppliers.	(Kee-hung Lai *et al.*, 2002); (Özkanlısoy, Ö. *et al.*, 2023).
		SCP-2	Improve operational efficiency.	(Kee-hung Lai, *et al.*, 2002); (Özkanlısoy, Ö. *et al.*, 2023).
		SCP-3	Improve service effectiveness for the consignee.	(Kee-hung Lai *et al.*, 2002); (Özkanlısoy, Ö, *et al.*, 2023).
		SCP-4	Improve supplier performance.	(Sindhuja, P.N.,2014)
		SCP-5	Reduce Supply chain responsiveness	(Sindhuja, P.N.,2014)
		SCP-6	Reduce responsiveness to customers	(Gawankar, S., *et al.*, 2016).

2.7.1 Top Management Commitment

The main construct of top management commitment includes item agility to promote flow synchronously for real-time information between the partners of the supply chain. The most important thing is to react quickly to any short-term shifts in supply or demand. The techniques are supplying data on supply and demand changes to supply chain partners continuously so they can react quickly, working with suppliers and consumers to rethink procedures, parts, and goods in ways that offer you an advantage over competitors, only complete items when you have precise knowledge about consumer preferences. To avoid manufacturing delays, maintain a modest stock of cheap, non-bulky product components. Because supply and demand in most sectors fluctuate more widely and quickly when it is compared with the past. A supply chain is managed by balancing costs as well as speeds, while agile ones react in a timely and economical manner. Businesses may increase supply chain agility by following these six guidelines and by regularly sending the partners information on changes in demand and supply where it can swiftly. For example, an E-hub has been established by Cisco that can use the internet to link suppliers with corporations. This makes it possible for every company to have access to the same demand and supply data simultaneously, to recognize changes in demand or supply issues right away, and to react cooperatively. An agile supply chain is created by making sure where no delay in information is. Cooperative partnership is established with customers and suppliers to enable businesses to rebuild components and design jointly. To expedite and precisely implement design and engineering modifications, Taiwan Semiconductor Manufacturing Company (TSMC), is the world's largest foundry of semiconductors, provides its suppliers as well as customers with proprietary tools, data, and models (Lee, 2004).

The main construct of top management commitment includes the item agility for the development of strong long-term collaborative relationships with the suppliers. The agility of the supply chain in organization is directly affected by the capacity for creating as well as delivering innovative products to the clients in an economical and timely manner in a continuously shifting global competitive environment. Although most people agree that supply chain agility has positive effects, there hasn't been much research done on how a business may become agile. This study first established the key factors to determine the attributes of flexibility of three crucial processes of supply chain—manufacturing, distribution/logistics, and procurement/sourcing. It then presented the framework of the supply chain process of an organization's flexibility considered as an important antecedent in the agility of the supply chain. We create agility as well as flexibility measures pertaining to the agility model of the supply chain using empirical data, and we test the model. The results show that a company's supply chain agility is positively and directly influenced by the degree of flexibility found in its manufacturing, sourcing, and procurement process; on the other hand, it is indirectly influenced by the degree of flexibility found in its logistics and distribution processes. The findings corroborate our theory that a company's internal supply chain's three process flexibilities work together to influence supply chain agility (Swafford *et al*., 2006).

The main construct of top management commitment includes the item adaptability for monitoring world economies to identify new supply bases and markets. One of the most crucial topics in supply chain management is the idea of supply chain agility, or SCA. Data from a field survey were used in this investigation. The findings offer empirical support for the special and vital role that logistics plays in assisting businesses in quickly and effectively responding to market volatility and other uncertainty. The results are distribution in a balanced way towards the development of capabilities in multiple logistics that include interfaces of information management and interface of demand and management that can be preferred with the resources towards the single capability development like the interface of information management that can be with limited resources that are available for the investment at the ease frequently. Previous studies indicate that logistics capabilities are crucial in attaining supply chain agility (SCA) due to the boundary-spanning nature of logistics. Nevertheless, there hasn't been any empirical research done on the connection between SCA and firm-specific logistics capabilities (Gligor & Holcomb, 2014).

The main construct of top management commitment includes the item adaptability for using intermediaries for the development of logistics infrastructure and fresh suppliers. As a result, the correlation between cost-effectiveness and agility is unclear because of the scant empirical investigation conducted by scholars. Uncovering the connection between agility and efficiency can also provide a clearer understanding of the relationship between the core lean and agility concepts, as waste elimination is the cornerstone of lean. By investigating the relationship between supply chain agility (FSCA), cost-effectiveness, and customer effectiveness in a range of environmental scenarios, the manuscript significantly advances agility research. We investigate the moderating impacts of environmental dynamism, munificence, and complexity using archive data. Some have stated that in extremely uncertain situations, businesses should use agile tactics, while in more stable environments, lean techniques. To find out if supply chain agility can also result in better performance for businesses working in stable conditions, we empirically challenge this assumption (Gligor *et al*., 2015).

The main construct of top management commitment includes the item Alignment for clearly laying out rules and responsibilities for customers and suppliers. An increasing amount of research has started to acknowledge that, in the age of supply chain management, it's critical to focus on the flexible supply chain rather than just the flexible factory. A large portion of the literature now in publication defines supply chain flexibility narrowly, characterizing it as merely a reactive strategy for managing uncertainty. Due to its origins in the manufacturing flexibility literature, supply chain flexibility is still mostly limited to the production setting, ignoring the significance of services. A common method for doing empirical research at the business level is a cross-sectional postal questionnaire, which does not address the inter-organizational aspects of supply chain flexibility (Stevenson & Spring, 2007).

The main construct of top management commitment includes the item Alignment Perfectly exchanging information with suppliers and customers. To attain greater flexibility in buyer-supplier pairings as well as in the larger supply chain or network, the study aims to present an empirical investigation of supply chain flexibility and poses the following question: what specific inter-firm techniques are employed? A qualitative investigation of a network including sixteen interconnected manufacturing firms is the methodology used. Face-to-face semi-structured interviews with top representatives from every organization. Numerous supply chain flexibility techniques are found; some of them support previous studies, while others are brand-new. Ten categories are created from them, and two overarching themes emerge. First, businesses employ a range of subcontracting and outsourcing strategies to lessen their internal flexibility requirements. The second related observation is that companies enhance the flexibility of the entire chain by forming enduring relationships with counterparties after externalizing the demand for flexibility. The capacity to alter counterparts is referred to by the authors as "configuration flexibility," and the ability to alter supply timing, volume, and design as "planning and control flexibility." Consequently, it is advised that businesses make difficult trade-offs between the two to maximize supply chain flexibility. To enable further testing and improvement, these are provided in a model (Stevenson & Spring., 2007).

The main construct of top management commitment includes the item customer and shareholder focus for having implementation, acquisition, shareholder focus and customer focus, benchmarking, and continual improvement. To fulfill the requirements of locating the right suppliers, building trust with the right partners, and supplying the right customers, organisations must utilize the concepts of supply chain management, or SCM. This study assumes that the organizations that make up the supply chain should have a shared vision and that it is impossible to maintain a long-term connection without these entities receiving concrete advantages. This research endeavors to ascertain the pivotal aspects of supply chain management and formulate theoretical structures from the viewpoints of the four participants in the supply chain: Retailers service product provider's logistics suppliers and equipment manufacturers (Srikantha Dath *et al*., 2009).

2.7.2 Supply Chain Collaboration

The construct supply chain collaboration includes the item information sharing for information sharing refers to the act of disseminating and capturing timely and relevant information for decision-makers to control and plan operations. An instrument to gauge the level of cooperation between suppliers and retailers two participants in a supply chain—is proposed by the study. The collaborative behaviors of incentive alignment, synchronization of decisions, and information sharing are all included in the suggested collaboration paradigm. To gauge the degree of collaborative practices, a collaboration index is presented. To gather information for testing and assessing the collaboration index, a survey of New Zealand businesses was undertaken. The survey's findings attested to the validity and dependability of the suggested collaboration index measure. Additionally, the results demonstrated a positive correlation between the collaboration index and operational performance (Simatupang & Sridharan, 2005).

The construct supply chain collaboration includes item decision synchronization and incentive alignment to joint decision-making in the operational and planning context. Companies are compelled by fierce competition to collaborate with their downstream and upstream partners in the supply chain. Benchmarking is the key to making sure the participating members are moving in the proper direction toward developing the best-in-class practice. All parties involved gain from benchmarking's promotion of group learning for performance enhancement. Nonetheless, prior studies have primarily concentrated on supply chain benchmarking inside the same organization as opposed to across different companies. A fresh viewpoint on collaborative learning among participating members that motivates them to enhance supply chain performance overall is necessary to comprehend inter-company benchmarking. The study aims to create a benchmarking system for supply chain collaboration by establishing a connection between collaborative enablers and collaborative performance measurements. The suggested benchmarking plan can be used to assess how well-participating members are currently collaborating on the supply chain, spot performance gaps, and organize improvement projects (Simatupang & Sridharan, 2004).

The construct supply chain collaboration includes the item topology. Configurations in the Supply chain can be known as topology. There are divergent and convergent topologies. It is clear from the examination of the 69 research publications that were chosen at random that there hasn't been any research on supply chain collaboration in the Indian setting. A balance between conceptual and empirical research types has been noted in the evaluated publications. It has been noted that the primary focus is on retailer organization and manufacturing. 28 variables influencing supply chain collaboration have been found through research of reviewed literature. In the body of existing research, the terms collaboration and coordination in the supply chain are used interchangeably. Two of the most heavily researched issues found in reviewed publications are the creation of a framework to quantify supply chain cooperation and the examination of the empirical relationship between supply network collaboration and improved supply chain performance. The cooperation between manufacturing companies and their suppliers has dominated the examined studies. The collaborations in organizations have not received much attention in articles. As a result, there is a research vacuum that has to be filled to handle collaboration with multiple-tier suppliers as well as downstream supply chain collaboration. Furthermore, the majority of the authors made the case that successful supply chain collaborations find information exchange to be of utmost importance. The primary advantages that have been noted include decreased costs, less inventory, improved visibility, and a decrease in the bullwhip effect. Thus, we can conclude that more research is required to understand supply chain collaboration, the causes of and advantages associated with information sharing in Indian manufacturing firms (Hundurkar *et al*., 2014).

The construct supply chain collaboration includes the item topology. Prior understanding of the effects of changes in the key parameters and constituents on the performance of a collaborative supply chain is made possible by modeling the elements of the chain, influenced by key parameters as well as various measures of performance in a decision support environment. This, in turn, makes it possible to identify the precise places where the supply chain itself might be enhanced, managing the chain's overall performance. The researcher demonstrates how the environment's components, performance indicators, and critical parameters are modelled. It also uses a case study to demonstrate how the decision support environment may be utilized to identify areas for improvement in a collaborative supply chain's performance. The commercial objectives of each participant must be in line with the cooperative supply chain's objectives, even though they may disagree. A performance trade-off balancing method that seeks to strike a balance between the independent and business goals of a cooperative supply chain may be used to achieve alignment (Angerhofer & Angelides, 2006).

The construct supply chain collaboration includes the item-enabling technology. Informational technology used in the supply chain can be referred to as enabling technology. Information technologies have the potential to be very useful for supply chain management, but their adoption is not always what is anticipated. We look at the incentive structures and coordination issues that arise when a manufacturer and a retailer pool their resources to invest in a new technology that could boost supply chain security and efficiency. We demonstrate that supply chain stakeholders in a decentralized supply chain face two distinct coordination challenges when investing in new technology, depending on the relative intensity of efficiency and security concerns: Stakeholders may not have enough motivation to invest when security concerns are not high enough to outweigh efficiency concerns; as a result, at least one stakeholder underinvests. The research indicates that external financial incentive mechanisms, such as tax incentives, should be taken into consideration as internal incentive mechanisms, like stakeholder cost sharing for investments, are unlikely to address this underinvestment. (2) Rather than a lack of motivation to invest in the technology, stakeholders may choose not to invest at all when security concerns outweigh efficiency concerns due to the unpredictability of other stakeholders' actions. Our work demonstrates that one method to reduce such behavioral uncertainty is by external actions, such as enforcing a penalty for a security breach (Lee *et al*., 2014).

An increasing amount of research indicates that companies can achieve better performance by managing their supply chains well. We present the results of focus groups with 46 supply chain executives in four US cities, to offer more detailed insights into the main causes and effects of supply chain effectiveness. We combine the results with existing research to create a testable model that suggests supply chain management practices impact a firm's success. The proposed supply chain model states with proper knowledge application has significant applications for the supply chain performance and focal firms. It states that trust, technology, knowledge base, and skill of organization in partners of the supply chain are the enablers in sharing knowledge in the supply chain (Crook *et al*., 2008).

The construct supply chain collaboration includes the item level of collaboration. The business strategy and market conditions dictate the appropriate and advantageous degree of collaboration. Outlined levels of cooperation, or include management, strategic, and operational levels. This study looked at how a cooperative initiative between suppliers and purchasers in a supply chain affects relationship results, commercial performance, and operational outcomes. The results of a collaborative project are thought to be influenced by the interdependence of information and processes, insights of supply chain partners as well as degree of cooperation among the organizations. The investigations made use of the survey data from suppliers and buyers across the broad spectrum of organizations and sectors. Among the participants, a high level of collaboration leads to improvements in relational and operational outcomes that are together for the improvement of profitability, organizational performance, competitive position, and asset utilization (Zacharia *et al*., 2011).

2.7.3 Supply Chain Management Rail transport

The study's construct of Rail transport for supply chain management contains the item Environment Energy. To produce liquid biofuels on a commercial scale using biomass derived from forests, a sizable geographic area would need to supply feedstock. If one intends to ensure that a particular biofuel product will fulfill GHG reduction standards, case-specific assessments are required. The feedstock composition for supply chain arrangements and emission of greenhouse gases depends on location. Geographic information system techniques were used to examine the availability of biomass, the transportation network, and GHG emissions. Life-cycle assessment was used to evaluate GHG emissions. The findings demonstrated that using railroads to move goods from far-off source areas can significantly lower the greenhouse gas emissions of supply chains. Additionally, although the emission of GHG in the supply chain with emission of gases, uncomminuted biomass when compared with the supply chain of fossil diesel (Jappinen *et al*., 2013).

The construct of the study Supply chain management rail transport includes the item Environment Energy. Globally, business managers and government officials alike are placing a growing amount of weight on the subject of sustainability. Businesses have realized that, in addition to being good for the environment, policies and tactics aimed at reducing greenhouse gas emissions also present significant business growth prospects. The majority of decisions that affect emissions and sustainability are made in the company supply chain, which is the subject of many such strategies. Examples of these decisions include distribution strategies, such as which facilities should serve which markets, facility placement, and the specification of transportation modes in supply chain logistic network management and design. In this work, a feasible hypothetical network was used as a case to construct a nonlinear mathematical model to facilitate sustainable logistic network planning. The created model differs from previous models in the literature currently in use in that it includes the cost of carbon emission due to transportation operations along the supply chain in addition to standard logistic expenses. Sensitivity analyses were carried out using a computer simulation designed to compare the effects of road and rail transportation modes on network configuration cost optimization, particularly concerning the overall emission cost and stock in the supply chain in the degree of customer service (Wanke *et al*., 2015).

Every year, millions of tons of aggregates are carried throughout Wales and England, raising ongoing worries about carbon emissions. The lengthy drives from quarries to construction sites and the fact that roads are the primary means of transportation are the main causes of that worry. This study describes the development of a spatial decision support system (SDSS) to analyze the effects of several scenarios aimed at lowering CO2 emissions. The SDSS consists of a GIS with a collection of spatial models (such as a microsimulation model and a spatial interaction model) supported by an intricate transportation network of roads and rail lines throughout Wales and England. Initially, the spatial interaction models are calibrated to replicate the current aggregate flows between local authority areas and quarries. The trip distance equivalent across the road and rail networks makes up the distance decay component. It is possible to create linear models based on these flows to calculate the quantity of CO2 emissions connected to the current set of flows. Next, several hypothetical situations are established to examine the effects of altering the production region, the degree of demand in specific regions, or the mode of transportation on the amount of CO2 emissions. The study illustrates how the SDSS may adapt to diverse spatial policies used at different phases of the aggregate markets supply chain (Zuo *et al*., 2013).

The construct of the study Supply chain management rail transport includes the item Cost and economic concerns. The cost of harvesting pulpwood from natural forests to expand Michigan's potential for forest products is examined in this study. The primary three distinct harvest prescriptions were modelled: clearcutting, 30% selective cutting, and 70% shelterwood cutting. The Forest Inventory and Analysis database was used to examine filled or overstocked stands before the prescriptions were applied. The primary transportation data was gathered from rail and truck companies with the information sources for determining costs. The following harvest systems were examined: chainsaws and skidder systems; mechanical cut-to-length equipment and forwarder; and mechanized whole-tree feller buncher with skidder and processor. Truck and bimodal (truck and rail) transportation solutions have been the subject of transportation analyses. Results and procedures outline the variety of information needed to analyze the logging supply chain's cost, highlighting the fluctuation in establishing a fixed cost for forest biomass removal activities (Abbas *et al*., 2013).

The construct of the study Supply chain management rail transport includes the item Cost and economic concerns. The economic and environmental consequences of switching 10% of truck-borne intercity freight to rail for the local supply chain. The freight-rail network offers a more affordable and fuel-efficient shipping option than trucks, which can also aid in reducing traffic congestion. The necessity for railroad system expansion is also heightened by the growing demand for rail transit. In this case study, we assume that 10% of Pennsylvania's truck-borne intercity freight will be moved to rail, necessitating a 10% increase in the freight-rail network in the form of new tracks, stations, maintenance and repair facilities, and locomotive production. The assessment models benchmark economic input and output had been developed for estimating air pollutants, CO2 emission, fuel and electricity usage, and economic activity of the supply chain (Henderickson *et al*., 2012).

The railroad is a crucial conduit for contemporary logistics. The primary factor influencing the cost of logistics is the cost of railroad freight. As a result, the study of railroad freight costs is important for the contemporary logistics network. For a very long time, Chinese train transit prices have stayed the same. The relevant government agencies modify the national rail freight rate according to various stages and special conditions. This pricing model accounts for time, which has an impact on how costs and rail freight prices relate to one another. However, it fails to take into account the region factor, which is becoming increasingly significant these days and contributes to flaws in the current rail freight cost-pricing methodology. Time and location are taken into consideration while establishing the rail freight cost-pricing model, which is done by applying the principles of transport economics to the analysis of the costs associated with rail freight. Rail freight and other factors should be gradually connected to develop the linkage mechanism, allowing railway freight prices to be modified by changes in costs (Yuqian & Sping, 2011).

The construct of the study Supply chain management rail transport includes the item Optimization. The subject of power coal transportation and inventory is examined in this work. We examine the current state of power coal transportation as well as the design of China's power coal supply chain. To lower the cost of the coal supply chain, we apply balanced transportation, a bi-hierocracy inventory model in coal inventory, and a joint optimization approach for rail transportation. These methods target variations in coal demand and capacity restrictions in railway transportation. Furthermore, we employ an empirical case study of the coal supply in Xinjiang to elucidate the model's economic viability (Zang *et al*., 2010).

The construct of the study Supply chain management rail transport includes the item Scheduling planning. Rail transport systems are becoming more and more important on a worldwide scale due to supply chain expansion. This is primarily because, in comparison to road transit, it is faster, safer, more dependable, less expensive, and environmentally benign. This chapter looks at the scientific literature, contemporary issues, the rail freight network's overview, and its function in the supply chain. Six key factors are taken into consideration while investigating rail network concerns: environment, cost, optimization, operation, planning, safety, and resilience (Gholamizadeh *et al*., 2024).

These days, production and transportation scheduling are inextricably linked since a well-coordinated response to an integrated problem can enhance the whole performance of the supply chain. Due to the widespread usage of rail transportation in supply chains, we have developed integrated production and rail transportation scheduling in this study. The challenge is to allocate orders for rail transportation and production schedules in a way that maximizes customer service while keeping overall costs to a minimum. Furthermore, we employ a few processes and heuristics to encode the model so that two competent metaheuristics can handle it: the Keshtel algorithm (KA), a newly designed algorithm, and a genetic algorithm (GA). The latter is initially employed in supply chain literature for a mathematical model. To enhance the algorithms' performance, the Taguchi experimental design approach is also used to set and estimate the appropriate values of the algorithms' parameters. Different issue sizes are used, and the computational outcomes of the algorithms are contrasted with one another, to assess the suggested algorithms' performance. Lastly, we look into how our algorithms perform when the size of the problem increases (Hajiaghaei & Aminnayeri., 2014).

Single-track sections are prevalent in many railway networks, especially in different supply chains. Depending on which station is the starting point for the trip between these two stations, the trains split into two groups for this type of segment that connects them. The trains in a group vary based on their cost functions. It is considered that the single track has enough length to allow multiple trains to move simultaneously in the same direction. In this research, polynomial-time solutions for various variants of this single-track, two-station train scheduling problem are presented. The objective functions of the models under consideration separate them from one another (Zinder *et al*., 2016).

The study's construct Safety and security of the items are included in the supply chain management rail transit. A consistent method for quantitative risk assessment in this process is now required due to the disastrous effects of hazardous material leaks from trucks. Thus, the purpose of this study was to use a fuzzy inference system and a Bayesian network to evaluate the quantitative risk associated with the transportation of hazardous commodities by road. To investigate the source and effect of material leaking from trucks, this study used a bowtie analysis in a Bayesian network. To ascertain the severity correction factor of the analyzed nodes and assess the seriousness of the health and safety implications, hybrid equations and a fuzzy inference system were employed. The quantitative risk was finally computed. According to the findings, there is a chance that vehicles transporting hazardous items will leak chemicals (Mohammadfam et al, 2020).

Hazardous material-using new technologies typically carry some risk. When technology is intended to be implemented extensively and used by a large number of people, it becomes more serious. The researcher's goal was to assess the possibility of a vapor cloud explosion during the hydrogen production process. Techniques: The traditional hazard identification method (HAZID) was used to identify potential dangers. Statistical information and already-existing records were used to estimate the frequency of the suggested situations. For consequence modeling, the PHAST professional software was utilized. Risks to the individual and the community were assessed. This cross-sectional investigation was carried out in a Tehrani hydrogen production plant between June 2010 and December 2011. Findings: The heat exchanger's full-bore rupture exhibited the greatest detrimental effect on distance. The desulphurization reactor's full-bore rupture posed the greatest individual risk, accounting for 57% of the total (Zarei *et al*., 2013).

Concerning driving crew assignments, it was discovered that most driving crews worked diligently with a desirable occupational outlook and pride and that they had strong senses of obligation for their jobs, which explained their aptitude for them.

However, it was shown that physical and psychological issues, such as boredom in daily life, excessive task loads, inadequate sleep, and physical exhaustion, all led to stress. The driving crews' stress levels were also elevated by their inconsistent work schedules, unpredictable lunch times, and the stress of providing on-time transit service while being immobilized for an extended period. When it came to external environmental elements, driving crews' stress levels increased almost four times more than other factors because they were anxious about potential accidents. Moreover, it was shown that the compensation and personnel systems had a strong correlation with the job stress experienced by the driving crews (Park *et al*., 2013).

The construct of the study Supply chain management rail transport includes the item Operation. This work aims to identify and analyze the opportunities provided by exchanging rail-wagon monitoring and tracing data for operations of actors in an automotive supply chain (SC) through a thorough case study. The study demonstrates how traffic authorities might improve their monitoring of infrastructure usage by exchanging data through a wagon tracking and tracing system. Transport clients will be able to track and trace containers and pallets as a result, which will enhance maintenance practices for transport companies (Mirabeiki & Sjoholm, 2012).

Supply chains are constructed in large part through transportation, which is also a major component of many newly developed supply chain management theories and techniques. ICT has been used more favorably in the business, operations, and engineering sectors in recent years. ICT potential and applications, however, are always changing; today's standard is tomorrow's obsolete in this regard. ICT is also playing a bigger role in rail transportation. Not only is it used for business applications like asset management, ticketing, and information broadcasting, but it is also used for mission- and safety-critical tasks, especially when building new infrastructure in the age of automated and high-speed trains. The capital-intensive nature and protracted gestation period of railway infrastructure represent a significant concern. Developing ICT for safety and mission-critical railway applications requires a significant initial investment of time and money, as well as careful planning to thoroughly analyze needs and product specifications. Long lead times and significant cost overruns are caused by the constantly changing ICT standards. Although the rail sector has adopted modern technology, railroads have yet to fully investigate several ICT innovations; financial and technical setbacks often induce caution. This study examines automated train operating technologies in detail as well as the function of ICT in a larger context of increasing transportation capacity (Narayanaswami & Mohan, 2013).

Due to its own industrial and inherent features, the logistics of railway electrification engineering are currently not transferable to other countries' departments, industries, or management information systems. The researcher proposed the supply chain management logistics structure in transportation holds the keys for analysing the information related to logistics and the design of management systems. Finally, utilising the object-oriented data model and data mining technology for computer-assisted decision systems in Railway Engineering Transportation for the distribution of the supply chain. By the use of information systems in supply chain management and object-oriented analysis the researcher examined the logistic system of railway electrification engineering (Deng, 2013).

2.7.4 Supply Chain Performance

The construct of the study supply chain performance includes the item Service effectiveness for shippers and Operations efficiency. The purpose of this research is to better understand supply chain performance (SCP) in transportation logistics and to create a tool for measuring it. A model for measuring SCP in transport logistics as well as an instrument for measuring it is created based on the supply chain operations reference model and different y. measurements. An instrument measuring the Consignee’s service effectiveness, service providers of transport logistics and operational efficiency, and service effectiveness of shippers was developed. It consists of 26 items. The empirical results imply that the measuring tool is valid and dependable for assessing SCP in transportation logistics (Lai *et al*., 2002).

The construct of the study supply chain performance includes the item Service effectiveness for consignees. These days, the measurement of SCP is an essential component of supply chain management since it helps supply chains and businesses alike identify possible issues and areas for improvement, assess process effectiveness, and improve the overall health and success of supply chains. By providing a more uniform, thorough, and current measurement scale based on the SCOR model version 13.0 performance measures in the disruptive technology era, this study hopes to further future research and practical applications. Techniques: Seven stages of the study were conducted, with a sample size of 227 companies for pilot data and 452 companies for main data. The steps include creating and refining the items, assessing the convergent, discriminant, and nomological validity, investigating the bias effect, and conducting exploratory and confirmatory factor analyses for the main study and pilot study. Results: A five-factor and thirty-one-item structure was created and verified for the scale. In conclusion: To understand the future supply chain landscape, it is imperative to monitor some critical trends and indicators now. The future supply networks are closely tracked by this measurement scale. Furthermore, the contributions of disruptive technologies and the supply chain management conceptual framework have validated the findings (Ozkanlisoy & Bulutlar, 2023).

The construct of the study supply chain performance includes the item Supplier performance and Supply chain responsiveness. A conceptual model was created and verified using existing supply chain security management and information security management literature. To gather information, a survey instrument in the form of a questionnaire was created and distributed to supply chain managers. Information was gathered from 197 companies across a range of industries. Data analysis for the study was done using both confirmatory and exploratory factor analysis. Additionally, SEM techniques were employed to fit the theoretical model and test the predictions. The study's findings show that supply chain operations, which in turn have a favourable impact on supply chain performance, are favourably correlated with information security infrastructure (ISI), which includes formal, informal, and technical security components in an intra- and inter-organizational setting. The report lays the groundwork for upcoming investigations into supply chain information security management. By clearly defining technical, formal, and informal information security policies for enhancing supply chain performance, the findings are anticipated to help communities of practice make better information security decisions in a supply chain environment (Sindhu, 2014).

The construct of the study supply chain performance includes the item Responsiveness to customers. The creation of carefully validated measurement tools and SCPM components is the study's primary contribution. The confirmation procedure follows the conventional guidelines for scale development. The goal of the study is to add to the body of knowledge regarding the SCPM in the Indian retail sector. This study examines the measuring scales' validity to help managers choose the right SCPM. Over time, a solid collection of recognized SCPMs and their application will inevitably make it possible to derive careful supply chain plans (Gawankar *et al*., 2016).

2.8 Research Gaps

2.8.1 Insufficient Adoption of New Technology and Techniques

The utilization of modern advancements which include the Internet of Things, Artificial Intelligence, and big data analytics optimization in improving the efficiency associated with operational activities in supply chain management encompasses their emphasis in the running of the systems. Indian Railways has been behind in the incorporation of such innovations which makes it difficult to enhance logistics operations, enable real time tracking, as well as other operational processes. Other works have reported that most of the enterprises experience impediments like lack of enough facilities, lack of proper skills training, and fear of changing (Gholamizadeh *et al*., 2024). This gap indicates a pressing need for research focused on the specific technologies that can be adopted by Indian Railways and how these technologies can be effectively implemented to enhance SCM performance.

2.8.2 Need for Eco-friendly, Sustainable Trash Management Solutions

Indian Railways indeed has an enormous scope for waste generation but does not use effective measures for waste management. The existing literature develops and commercializes other technologies but does not encourage the exploration of green technologies such as recyclables and waste to energy. Studies indicate that the supply chain operations in the railway sector can be safely steered in the green direction, especially in the area of waste management, where the current operations cause maximum damage to the environment (Jäppinen *et al*. 2014). This gap needs more detailed projects dealing with waste management for the railway sector.

2.8.3 Infrastructure Challenges in SCM are Not Adequately Addressed

The efficiency of a supply chain management system is highly dependent on the existing infrastructure. In the case of Indian Railways, it confronts several challenges due to the infrastructure which include old structures, fewer logistic chains, and weak intermodal connectivity. Above all other issues, the literature on the subject seems insufficient in determining the effect of infrastructure on the performance of SCM.

There is no scholarship that examines the infrastructure gaps and the enhancement that are necessary towards proper SCM in the railways (Narayanaswami & Mohan 2013). It is likely that such in-depth investigation of infrastructure enhancement would allow better understanding for better supply chain operation.

2.8.4 Operational Issues Lacking Comprehensive Investigation

The effectiveness of supply chain management in the context of the Indian Railways requires research into operational aspects such as the management of costs, efficiency of the designs, and the timelines for delivery, all of which have not received sufficient attention. This is because what many of these studies treat as an issue, many others tend to treat it as a mere walkover. Certain issues like the structuring of operational costs and the effects of these on SCM performance are not well tackled (Lee, 2004). There is need for a systematic approach to these operational problems so that appropriate measures to improve efficiency and overall SCM on Indian Railways can be recommended.

2.8.5 Disconnection in Regulatory Compliance and Policy Execution

Compliance is an important part of supply chain management. But there is an intersection between policy and implementation within the Indian Railways literature revealing that policy implementation is related to safety standards. Security and the environment is often scattered. This leads to inefficiency (Ozkanlisoy & Bulutlar, 2023) - Research is needed to explore how governance frameworks can be aligned with operational practices to improve compliance and overall SCM performance. Understanding this relationship helps Indian Railways improve SCM practices and ensure better compliance with national and international standards.

2.8.6 Lack of Comprehensive Performance Assessment Systems

Indian Railways' lack of an optimized performance evaluation system for SCM is a major challenge. Current frameworks used for performance evaluation are inadequate to deal with the unique operational complexities faced by the rail sector (Zang *et al.*, 2010). There is a need for research that develops criteria and evaluation systems. Comprehensive, designed specifically for the railway context. This can provide insights into the effectiveness, efficiency and scope of improvement in SCM.

2.8.7 Limited Research on Supply Chain Agility, Market Demand Forecasting, and Strategic SCM Planning

Supply chain agility is essential in responding to market changes. But research into supply chain agility Forecasting market demand and specific strategic planning for Indian Railways is limited. Studies suggest that increasing supply chain agility can improve responsiveness and efficiency (Park *et al*., 2013). There is an urgent need for research focused on exploratory methods to increase agility. Accurate demand forecasting and strategic SCM planning tailored to the rail sector's unique challenges

2.8.8 Focused Research Needed to Improve Responsiveness and Resilience in Indian Railways' SCM

Improving responsiveness and flexibility in supply chain management is essential. This is especially true in the case of unexpected disruptions, such as natural disasters or social and political factors. Research has shown that increasing supply chain resilience can lead to better recovery and sustainable operations (Sindhu, 2014). There is a significant gap in the literature on how Indian Railways can develop strategies to improve supply chain responsiveness and flexibility. Focused research efforts are needed to address these challenges.

2.9 Research Objectives

The literature review was carried out to fulfill the research gaps based on the research objectives.

1. To study the Supply Chain Issues in Rail Transport
2. To study the barriers in Supply Chain Management in Rail Transport
3. To analyze the Supply Chain Management in Rail Transport
4. To study the Supply Chain Performance of Rail Transport

2.10 Motivation for the Research

Motivation for the research is based on following activities are being held nationally and internationally in the area of supply chain management in rail transport:

- Conferences are conducted at both national and international levels,
- Research papers,

- Seminars, and workshops
- Courses taught in Engineering Institutes and Universities

The motivation for pursuing research in the area of supply chain management in rail transport will further help in improving efficiency, reduce costs, and enhance the reliability of logistics and transportation systems. The research will address challenges such as delays, bottlenecks, and integration with other transport modes, this research aims to optimize the flow of goods, increase sustainability, and contribute to the overall performance of the rail transport sector.

2.11 Conclusions

In this chapter, the systematic review on the supply chain management issues, and challenges, and identifies different constructs like top management commitment, supply chain collaboration, supply chain management rail transport, and supply chain performance is presented. From the literature it has been observed that significance of the rail transport system increased globally by the supply chain development. The literature reports major attributes like reliability, safety, lower cost, high speed and eco-friendly nature made rail transport as more preferable compared with road transportation. Railways play a necessary role in the supply chain of the nation. Goods can be moved easily by rail in a safer, more efficient, and less expensive way. The progress in management principles and techniques improves facility usage, delivering speed, service quality, operational cost, moving load, and energy saving. The efficiency of moving products can be determined by supply chain management in the operations of transport. Quality of Transportation Management including cost, customer satisfaction, and service level can directly impact supply chain performance.

CHAPTER 3

RESEARCH DESIGN

3.1 Introduction

The research design specifies the conceptual framework and research techniques used in the study. Similarly, it provides information about the research processes used, the types of data gathered for the study, and the research methodology. Before the data is submitted for further research, a wide range of criteria and tests are specified to ensure its validity and dependability. Finally, it includes information on the statistical programs and tools used to examine the data. This study used a quantitative research design. The inquiry used descriptive and causal research designs as decisive methods. The study's main objective is to determine the supply chain's performance, issues, obstacles, and problems in Indian rail transportation. After reviewing existing models and literature, the researcher has determined that supply chain performances (SCP), supply chain collaborations (SCC), supply chain management rail transports (SCMRT), and top management commitments (TMC) are the four primary contributing elements in this respect. We looked at how the above factors affected Top Management Commitments (TMC), Supply Chain Collaborations (SCC), Supply Chain Management Rail Transports (SCMRT), and Supply Chain Performances (SCP) to make the structural equation model (SEM). This model can find out how different hidden variables from outside of rail transport affect the hidden variable "Supply Chain Performances (SCP)." These identified variables include Top Management Commitments (TMC), Supply Chain Collaborations (SCC), and Supply Chain Management Rail Transports (SCMRT).

3.2 Sources of Data

Using a surveying approach based on a questionnaire, the necessary data for the research was collected. A self-administered structured questionnaire approach was used to gather primary data. To comprehend the idea of supply chain performance on rail transport, secondary data was gathered from a variety of officially published academic papers, books, and websites about supply chain management from Scopus, WOS, ABDC, Google Scholar, Research Gate, SSRN, and the Academia database.

3.3 Research Instrument

AHP and TOPSIS method was employed to ensure that the selection process was as clear as possible. This technique demonstrates not only the relative qualities of the many solutions to a Multi-Criteria Decision Making (MCDM) issue but also shows the relative merits of those answers. Even though the AHP technique is a highly subjective one, the information needed to complete it is collected from the decision-maker of a firm either by direct questioning or by using a questionnaire. Further, the identified obstacles are analysed in this part using MCDM approaches. The principal methodologies employed are fuzzy MICMAC (FMICMAC) analysis and modified-total interpretive structural modeling (M-TISM). Further, the primary data was obtained by a well-structured questionnaire that was distributed in person to the Supply Chain Performances (SCP), Supply Chain Management Rail Transports (SCMRT), Top Management Commitments (TMC), and Supply Chain Collaborations (SCC). The questionnaire was made up of statements that measured supply chain performance using a five-point Likert scale.

3.4 Development and Validation of Data Collection Instrument

A critical first step in every research effort is the development of a valid and trustworthy research instrument. An organized questionnaire was employed to gather data for this research investigation. Utilizing validity and reliability tests, the validation of the gathered data was also examined.

3.4.1 Validity Testing and Reliability Testing:

Analyzing the data collection tool's capabilities to ascertain whether or not it can measure the relevant variables is known as validity testing. Validity testing includes content validity testing.

Content Validity:

An extensive collection of components and structures makes up a research instrument. These are produced by focus group discussions, the current literature study, and the evaluation of proven models. Ensuring the statements in the study instrument were clear and had the necessary content validity came next, once the necessary variables had been generated. A meticulous validation procedure was used for this. Initially, the survey instrument was sent to three highly qualified academics, and their comments were noted. To make the questionnaires more accurate, understandable, and practical, the experts' recommendations were taken into consideration and the elements were added, removed, and correctly modified.

Reliability Testing:

A standard measurement scale was thought to exist after a trial survey of thirty respondents from the suppliers of materials to Indian rail transportation. Following the conclusion of the pilot survey, the validity and reliability of the scale were assessed using the appropriate methodologies. The measurement scales underwent appropriate modification. The researcher was able to improve the questionnaire with the aid of this process. The enhancements were put into practice after a careful examination and suggestions from subject matter specialists. As the most common measure used to assess the data's internal consistency, the researcher used Cronbach's alpha test (Cronbach, 1951) to verify the correctness of the data after the pilot study data collection. An alpha value between 0.7 and 0.8 is often thought to be appropriate. The dependability coefficient for this research is 0 to 1, based on Cronbach's alpha. This study's factors all have alpha values greater than 0.7. As a result, every indication for every variable in the questionnaire was kept.

3.5 Sample Population

"The entire group of people, events, or things of interest that the researcher wishes to investigate" is the definition of a sample population in research. According to Sekaran and Bougie (2010), it is the set of individuals, occasions, or subjects of interest for whom the researcher wishes to conclude using sample statistics. The study's sample population consisted of material suppliers to Indian rail transportation. The industry's suppliers have positions as CEO, Sr. Manager, Manager, Board Member, and Administrator.

3.6 Sampling Element

According to (Malhotra and Dash, 2011), "an element is the object about which or from which the information is desired." The suppliers who hold positions in the industry as CEO, Sr. Manager, Manager, Board Member, and Administrator make up the sample element for this research.

3.7 Sampling Units

The suppliers who provide materials such as electrical components, automated parts, electronic parts, and consumer products and who hold positions as CEO, Sr. Manager, Manager, Board Member, and Administrator make up the sample unit for this research.

3.8 Determining the Sample Size:

For AHP & TOPSIS approach 110 respondents from the supply chain industry, including logistics experts, suppliers, and railway service managers were considered for the study to understand the issues faced in supply chain in Indian rail transport and for M-TISM & FMICMAC, 32 experts, selected through purposive sampling, including supply chain consultants, government regulators, and industry stakeholders were considered for the study to identify the barriers in supply chain in Indian rail transport.

Further, two methods are available for determining sample size in PLS-SEM: statistical power analysis (Cohen, 1992) and the rule of thumb (Barclay et al., 1995); (Hair et al., 2014). It is recommended to utilize a sample size ten times larger than the maximum number of structural paths in the structural model that lead to a single build. Formative indicators are not a part of this inquiry. Therefore, it is no longer relevant to the research to recommend that the sample size be 10 times the number of formative indicators. Nonetheless, the research's endogenous constructions, supply chain performances (SCP), are measured via three structural routes: supply chain collaborations (SCC), supply chain management rail transports (SCMRT), and top management commitments (TMC).

By generalizing, the sample size should be at least 50 respondents or 10 times the maximum number of structural paths to a given construct. The number of predictors, effect magnitude, and statistical power analysis determine the PLS-SEM sample size (Roldan & Sanchez–Franco, 2012). In terms of the theoretical relationship between the study's aspects, the researchers expect a significant yet manageable impact. This is because every single consumer may be aware of the distinctive characteristics of the study. Five distinct factors predict the endogenous construct of the research, which is customer perception. A minimum sample size of 91 would be optimal, as a medium effect size may have up to five predictors. The extant literature suggests that the number of predictors of the endogenous construct should be multiplied by the effect size for a

Power =.80 and Alpha =.05 to get an acceptable sample size. The power analysis (Table 3.1) of Cohen (1992) and Green (1991) are suggested for this. Green's (1991) power chart (Table 3.2) is used to calculate sample size.

Table 3.1: Power Analysis

Number of Predictors	**Sample Size**		
	Effect Size		
	Small	**Medium**	**Large**
1.	390	53	24
2.	481	66	30
3.	547	76	35
4.	599	84	39
5.	645	91	42
6.	686	97	46
7.	726	102	48
8.	757	108	51
9.	788	113	54
10.	844	117	56
15.	952	138	67
20.	1066	156	77
30.	1247	187	94
40.	1407	213	110

Source: Green (1991, p.503)

Table 3.2: Sample size recommendation in PLS-SEM for obtaining statistical power of 80%

Maximum Number of Arrows Pointing at a Construct	Significance Level											
	1%				5%				10%			
	Minimum R^2				Minimum R^2				Minimum R^2			
	0.10	0.25	0.50	0.75	0.10	0.25	0.50	0.75	0.10	0.25	0.50	0.75
1	158	75	47	38	110	52	33	26	88	41	26	21
2	176	84	53	42	124	59	38	30	100	48	30	25
3	191	91	58	46	137	65	42	33	111	53	34	27
4	205	98	62	50	147	70	45	36	120	58	37	30
5	217	103	66	53	157	75	48	39	128	62	40	32
6	228	109	69	56	166	80	51	41	136	66	42	35
7	238	114	73	59	174	84	54	44	143	69	45	37
8	247	119	76	62	181	88	57	46	150	73	47	39
9	256	123	79	64	189	91	59	48	156	76	49	41
Source: Cohen, J.A. Power primer. Psychological Bulletin, 112, pp.155-519.												

The R^2 level also influences sample size. As a result, while choosing the sample size, variables including the number of arrows pointing toward a construct, the minimum ideal R^2 level, and the significance level are taken into account. This contributes to achieving the required 80% level of statistical power. In the current study, the dependent construct of the research model is represented by up to five arrows. The R^2 level of 0.25 would be regarded as the very least acceptable threshold at a significance level of 5%. Considering these parameters, a sample size of seventy would be acceptable.

3.9 The Conceptual Model for the Study

The following is the conceptual model developed for the study exhibited in figure 3.1

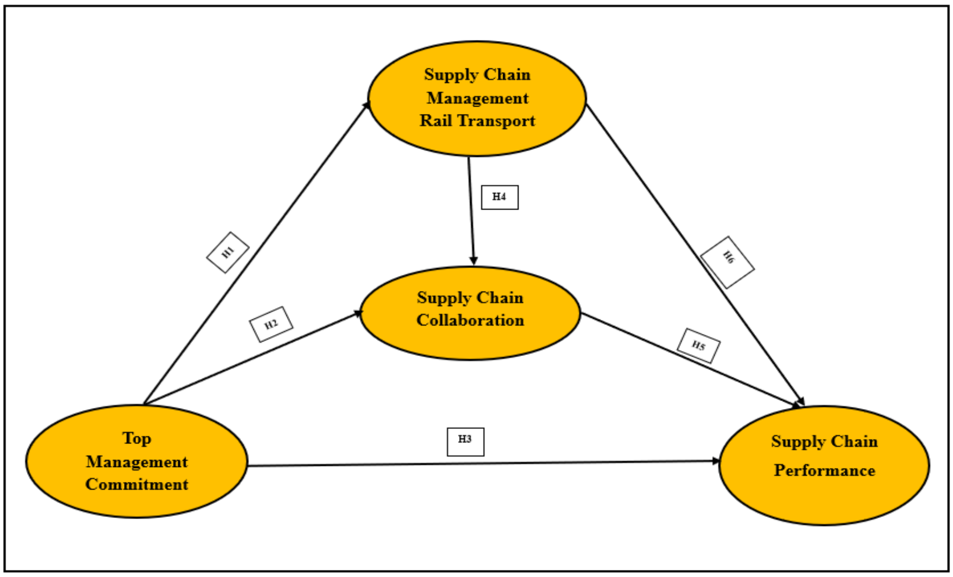

Figure 3.1: Conceptual Model for the study

3.10 Hypotheses for the Study

Following are the hypotheses for the study to measure the objectives:

H1: Top Management Commitment significantly influence Supply Chain Management Rail Transport

H2: Top Management Commitment significantly influence Supply Chain Collaboration

H3: Top Management Commitment significantly influence Supply Chain Performance

H4: Supply Chain Management Rail Transport significantly influence Supply Chain Collaboration

H5: Supply Chain Collaboration significantly influence Supply Chain Performance

H6: Supply Chain Management Rail Transport significantly influence Supply Chain Performance

3.11 Factors used in the Study

Factors such as integration system, financial behavior, and management perspective affecting availability, quality, and reliability of railway service were identified for AHP & TOPSIS analysis. Barriers including stakeholder influence, governmental regulations, and market volatility were identified for M-TISM & Fuzzy MICMAC analysis. Further, "Top Management Commitments (TMC), Supply Chain Collaborations (SCC), Supply Chain Management Rail Transports (SCMRT), and Supply Chain Performances (SCP)" were the key variables used in the study for SEM development. Indicators of the key variables are listed in Table 3.3.

Table 3.3: Key Variables and Indicators

S.No.	Construct	Items	Item Name
1	Top Management Commitment (TMC)	TMC-1	Developing strong, long-term, collaborative relationships with suppliers
		TMC-2	Using intermediaries to develop fresh suppliers and logistics infrastructure.
		TMC-3	Freely exchanging information with suppliers and customers.
		TMC-4	Having a clear customer and shareholder focus
		TMC-5	Supporting the acquisition and implementation of appropriate information systems
		TMC-6	Benchmarking and continual improvement
2	Supply Chain Collaboration (SCC)	SCC-1	Improve information sharing.
		SCC-2	Decision synchronisation
		SCC-3	Improve incentive alignment
		SCC-4	Improves the supply chain configuration.
		SCC-5	Improve the enabling technology.
		SCC-6	Enhanced level of collaboration

S.No.	Construct	Items	Item Name
3	Supply Chain Management Rail Transport (SCMRT)	SCMRT-1	Designs of specialized engineering related to the upgrading locomotive power supply systems
		SCMRT-2	Enhance optimal systems at a reasonable cost and receiving the highest profit.
		SCMRT-3	Optimisation to achieve maximum energy and minimum consumption.
		SCMRT-4	Introduction of mathematical algorithms for planning and scheduling
		SCMRT-5	Improvement of specialised approaches to the safety assessment of railway systems in a dynamic framework.
		SCMRT-6	Development of a specialized method for analyzing the performance errors of operators in digital rail control rooms.
4	Supply Chain Performance (SCP)	SCP-1	Improve service effectiveness for suppliers.
		SCP-2	Improve operational efficiency.
		SCP-3	Improve service effectiveness for the consignee.
		SCP-4	Improve supplier performance.
		SCP-5	Reduce Supply chain responsiveness
		SCP-6	Reduce responsiveness to customers

3.12 Data Cleaning

"Straight lining" was examined in every answer. No "straight lining" form instances were found. That being the case, none of the sample observations needed to be discarded. A check was also made for outliers in the data set of sample observations. The data set was examined and the outliers were identified using box plots in IBM SPSS statistics. Additionally, it underwent the process of being transformed into a standardized data collection. The aim of this was to identify data that deviated from the projected values of +3 or -3. There was a middle ground for the observation. These data points were also replaced with suitable values using the mean replacement technique.

3.13 Data Distribution

Next, the data set was verified in order to ascertain the values of Skewness and Kurtosis. Both skewness and kurtosis readings fell between +1 and -1. The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to further investigate the data's normality. It was found that the distribution of the data was non-normal since the significance level was less than 0.05. The results of these tests confirm that these differences are significant (Field, 2009).

3.14 Data Analysis Method

The performance of the model has been tested in the current study using PLS-SEM modeling (Hair et al., 2011). No assumptions on the distribution of the data were made throughout the evaluation process of the data in the current study. Additionally, this experiment has been conducted using a reflective measurement methodology. A mediating component is also a part of the model employed in this study. This explains the model's complexity. In light of these factors, it is advised to analyze constructs and related data using the PLS-SEM approach. Furthermore, the goal of this research project is to ascertain if certain contextual elements really serve as the determinants of consumer impression. Thus, it can be concluded that the PLS-SEM method is appropriate for data analysis.

3.15 Data Characteristics

Data from 145 respondents were used in the present study. Data are assessed without being limited by distributional assumptions. The PLS-SEM approach has been employed since it is appropriate for this study endeavor given the data properties of the present inquiry. (Hair et al., 2014; Nijssen & Douglas, 2008; Birkinshaw et al., 1995; Reinartz et al., 2009; Green & Ryans, 1990; Henseler, 2010; Henseler et al., 2009).

3.16 Model Properties

This study uses a well-developed model. Its inclusion of a mediating idea explains why. Furthermore, this study aims to ascertain if the exogenous qualities that have been found are the main factors that influence customers' perceptions. For model formulation and evaluation in the ongoing research effort, the PLS-SEM technique was chosen primarily for these reasons (Henseler et al., 2009; Hair et al., 2012; Hair et al., 2014; Cenfetelli & Bassellier, 2009; Diamantopoulos et al., 2012). The current research project has chosen a reflective measuring strategy to meet the study objectives. Specifically, the PLS-SEM technique is required in the present study because of the model's complexity.

3.17 Model Evaluation

There are independent variables in this research. Because the parsimonious structural model is necessary, it is imperative to employ the PLS-SEM approach (Alpert et al., 2001). To highlight specific reasons why the PLS-SEM approach was used in the present experiment, the description above may be summarized. For many reasons, including model complexity, the necessity to identify driving constructs of customer perception, and the inclusion of a mediating construct, the present study used the PLS-SEM approach (Hair et al., 2014, p. 19).

3.18 Scale of Variables

There are three exogenous constructs in this research. The idea under consideration is evaluated on a Likert scale. The replies are numerical. A Likert scale is used to gather data on the mediator. The study's endogenous construct is the idea of the customer's perception. Multi-item measures were used in this study's data gathering and analysis. Response 1 represents negative appraisal, whereas response 5 captures positive evaluation. To elicit replies from the individuals who were intended to be respondents, the study used an ordinal scale called the Likert scale (Likert, 1932). The responses have been carefully spaced out to guarantee fair distribution. Every answer point in between the two extremes, such as "Very High" and "Very Low," is thus designed to be evenly spaced. Consequently, the responses for this study were compiled using a five-point Likert scale. The range of answers is denoted by the digits 5 and 1, respectively, which stand for the two extreme replies, "Very High" and "Very Low."

3.19 Research Tools and Software Package Used

The gathered data were analyzed using a variety of statistical procedures, including factor analysis with Microsoft Excel, F-square, Q-square, Smart PLS-SEM 3, IPMA, and reliability and validity tests.

3.20 Research Techniques

Utilizing statistical tools, the primary data collected from the surveys was tabulated and assessed. The data collected from primary sources was examined and interpreted using a variety of statistical techniques often used in social science research, including univariate, bivariate, and multivariate analyses.

For AHP & TOPSIS analysis, structured questionnaires were distributed to 110 respondents to gather insights into the key issues affecting supply chain management in railways. The factors identified include integration systems, financial behavior, and management perspectives. AHP is used to establish a hierarchy of factors, where respondents will compare the relative importance of each factor in pairwise comparisons. This will allow the development of a weighted score for each factor. Following the AHP, TOPSIS is employed to rank the alternatives based on their closeness to the ideal solution. The factors will be assessed based on criteria such as availability, quality, and reliability of railway services. The results will highlight the most critical issues in SCM that require attention, ranked in order of their impact on service quality.

For M-TISM & Fuzzy MICMAC Analysis, a Delphi method will be used to gather expert opinions from 32 stakeholders and industry experts. The objective is to identify and validate the key barriers in supply chain management. M-TISM Methodology helps in identifying the barriers and classify using MCDM techniques. Further, Initial and final reachability matrices will be developed to map the relationships among barriers. Additionally, M-TISM will be used to create a structural model of barriers, demonstrating their interdependence and relative influence on the supply chain. Fuzzy MICMAC will be used to assess the driving and dependency power of each barrier. Further, Fuzzy reachability matrices will be developed, and driving-dependency diagrams will be plotted to visualize the influence of each barrier on the supply chain. The results will identify the most influential barriers, categorize them as driving or dependent, and provide actionable insights for overcoming these challenges in the supply chain.

Further, the study analysed the identified factors by reliability test using Cronbach Alpha was run. The validity of the measures was assessed using factor analysis. After measuring the relationship between the variables and assessing the theoretical model using appropriate bivariate and multivariate analyses, the measurement model was examined using the SEM model.

Test of Reliability: Reliability is defined as the consistency of a variable or group of variables about the phenomena that they are meant to assess (Hair et al., 2006). The level of "Top Management Commitments (TMC), Supply Chain Collaborations (SCC), Supply Chain Management Rail Transports (SCMRT), and Supply Chain Performances (SCP)" is measured for consistency using Cronbach's alpha and Composite reliability. According to Hair et al. (2006), the dependability value should be more than 0.70 and may vary from 0 to 1.

3.21 Validity Test

Validity is the ability of a measuring scale to measure what it is intended to measure (Zikmund, 2003). Reliability testing is a requirement for validity and an instrument may or may not pass it. Construct validity and content (face) validity are the two fundamental types of validity. Content validity is the subjective consensus among experts that a measuring instrument logically seems to measure what it is intended to examine. The measuring scale was given to professors with backgrounds in management, marketing, and statistics as part of the ongoing research project. Average Variance Extracted analysis is used to verify the construct, and a minimum threshold value of 0.50 is needed.

3.22 Structural Equation Modeling (SEM) and Path Analysis

Structural equation modeling (SEM) is a multivariate statistical analytic technique used to examine the underlying connections between latent and measurable variables. Path analysis is used to quantify the causal links between the components. The influence of "Top Management Commitments (TMC), Supply Chain Collaborations (SCC), Supply Chain Management Rail Transports (SCMRT), and Supply Chain Performances (SCP)" was assessed in the present study using SEM.

3.23 F-square

It is estimated how much one independent variable influences the other. The broad principles that prior research has supported for assessing the importance of the effect size are as follows: the impact size values of 0.35, 0.15, and 0.02 are considered big, medium, and small effect sizes, respectively (Cohen, 1988).

3.24 Q-square

The Q-square value, a measurement of the predictive importance of the model with a value larger than zero, was obtained in this study using the cross-validated redundancy approach (Hair et al. 2014). Recommend computing the Stone-Q^2 Geisser's value to assess a model's predictive power (Geisser, 1974; Stone, 1974). It displays how the route model predicts well-observed values.

3.25 Important-performance matrix analysis (IPMA)

The relative performance and importance of exogenous and endogenous factors are shown using important-performance matrix analysis (IPMA), also known as important-performance map analysis. The index values of exogenous constructs indicate their performance, while their cumulative impacts demonstrate their significance. The importance of the route diagram shows the whole influence on the final endogenous variable. Performance makes latent variable score capability visible.

3.26 Conclusions

The chapter presents a detailed research design that encompasses how the study, which aims to address the issues and challenges in supply chain management through the application of sophisticated multi-criteria decision-making methods, will be executed. This also shows the techniques that will be adopted in the performance analysis of the supply chain within Indian rail transport using SMART PLS. The research makes use of both subjective and objective methods with the determination of critical service expectations and service quality issues in supply chains by AHP and TOPSIS. Aligning with this focus, supply chain performance barriers to M-TISM and Fuzzy MICMAC such stakeholders, possible government policies as well as market fluctuations are considered and their respective influences are analyzed and the most important factors affecting performance are identified.

This chapter provides information on the sampling techniques adopted, the techniques for data collections as well as the research tools that were used to examine the research questions in a systematic and an effective investigation. All these methods help in improving the study by presenting the perspectives that facilitate dealing with the issues entrenched in supply chain management. This definitional and the conceptual basing of the research study will serve as the main bulwark of the rest of the research study so that the research is not only theoretical but also non-reclusive as far as the targets are concerned. Subsequent chapters helps in understanding the issues, barriers and performance by using applied methodologies.

CHAPTER 4

INDIAN RAILWAY'S SUPPLY CHAIN PARAMETERS EVALUATION: AN APPLICATION OF AHP AND TOPSIS

4.1 Introduction

Supply chain management (SCM) plays a key role in the operational efficiency of large logistics networks. In the case of Indian Railways, it is crucial to ensure that the movement of goods is both timely and orderly. Indian Railways is one of the largest railway networks in the world. But it faces significant challenges in optimizing supply chain processes. Infrastructure complexity large scale of operations and participation of a variety of stakeholders this enables efficient resource management from intake to delivery. It's a daunting task. Although advanced techniques such as analytical hierarchy process (AHP) and technique for priority by similarity to ideal solutions (TOPSIS) have been developed, several problems such as system integration, economic constraints have been developed. And management inefficiencies remain (Awasthi, 2018; Ipinazar, 2021). Addressing these challenges is critical to improving the returns of supply chain management in the Indian railway system. They still struggle with efficiency, quality, and service availability.

This chapter uses a structured multi-criteria decision-making methodology to estimate the supply chain parameters of Indian Railways using the Analytic Hierarchy Process (AHP) and TOPSIS methods. The methodology consists of several key steps such as (1) Identification of parameters: Important parameters for supply chain management related to Indian Railways such as availability. The quality of train services and their availability has been identified through expert consultation. (2) Data Collection: Four individual rankings were compiled from 110 railroad decision-making experts. A pairwise comparison matrix was created to compare experts' views on the relative importance of these parameters. (3) Application of AHP: The AHP technique is used to create a pairwise comparison matrix for each parameter. This step allows you to calculate consistency ratios to ensure that expert ratings are reasonable and consistent. A standard matrix was created to assess the relative significance of each criterion. (4) Validation using TOPSIS: The TOPSIS method is then used to validate the results from AHP by evaluating how close each alternative is to the ideal solution. This helps in ranking the supply chain parameters based on the specified results. (5) Model Development: Integration of both AHP and TOPSIS results in a model that provides a comprehensive assessment of the supply chain management system in Indian Railways.

4.2 Analytic Hierarchy Process

The decision-making techniques are used to measure the underlying mechanism of the parameters of the various systems. Many qualitative and quantitative techniques have been used in different areas of SCM. AHP is a decision-making framework and mathematical technique developed by Thomas L. Saaty in the 1970s. It ensures that the selection process is as clear as possible. It helps to solve complex problems by structuring them into a hierarchy of criteria and alternatives and then systematically evaluating and comparing these elements. This technique demonstrates not only the relative qualities of the many solutions to a Multi-criteria Decision Making (MCDM) issue but also the relative merits of those answers. Even though the AHP technique is a highly subjective one, the information needed to complete it may be collected from the decision-maker of a firm either by direct questioning or by using a questionnaire. (Awasthi, 2018). AHP includes a consistency check process that helps decision-makers ensure that their judgments and preferences are logically sound and free from inconsistencies. The following are some of the factors that are generally acknowledged in the literature as making the supplier selection decision-making process tough and/or complicated: The supplier selection process is a complex challenge, and as a result, it is a multi-attribute decision-making problem to solve (Adeodu, 2021). It has the advantage of demonstrating how potential changes in priority at higher levels might impact the priority of lower-level criteria. As a bonus, it provides the buyer with an overview of the criteria as well as their functions at lower levels as well as their objectives at higher levels. Furthermore, the stability and adaptability of AHP in the face of changes within and additions to the hierarchy are important advantages to consider (Ipinazar, 2021). With the method's ability to rank criteria according to the buyer's requirements, more accurate supplier choices may be made. The AHP technique uses a natural, pair-wise comparison to compare criteria or alternatives to determine the optimal choice. Uses a known and verified number system for this purpose, which has been proven in practice and tested in various physical and decision-making scenarios in the actual world. This scale is utilised to make judgments based on ratios of individual preferences. Each option has a scale weight that may be added to generate an additive weight that is linear (Kirytopoulos, 2008). For example, it may be used to compare and rank the options, which helps in making an informed selection. It is a powerful operational research tool to structure complicated multi-criterion issues or judgments in a wide range of fields such as logistics, supply chain management, marketing engineering, and education. Apart from using easily accessible expert judgment data, it can reconcile disparities in expert judgments and perceptions (inconsistencies) and the AHP may be implemented using Expert Choice Software (Wang, 2004). Our thoughts and priorities may be organized by the choice being broken into its parts. The steps of the AHP method are presented in Fig. 4.1.

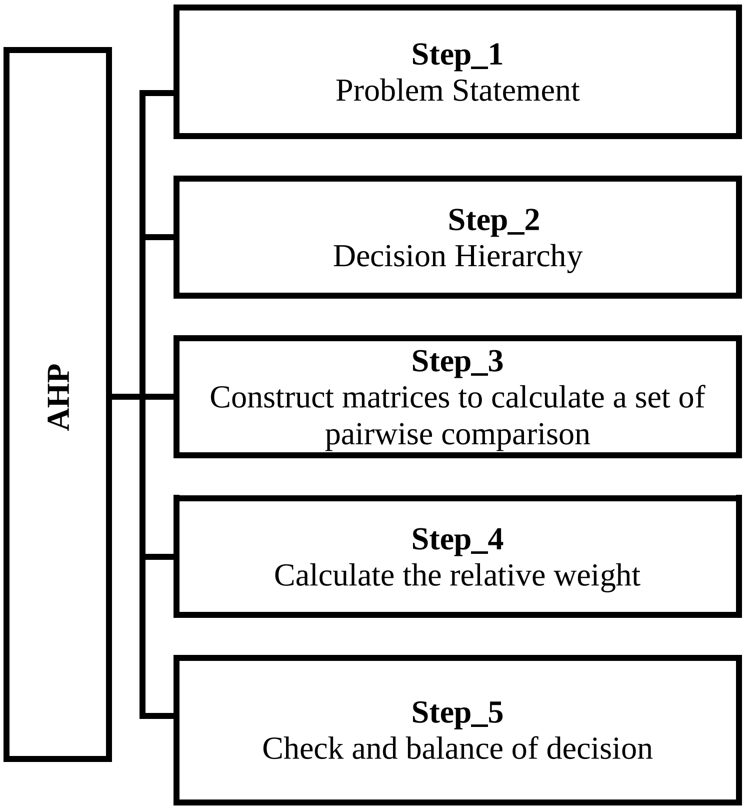

Figure 4.1: Flow chart of AHP Method

The decision problem considered in this study is how to determine which alternative is best given the information in the decision matrix presented above. Evaluating the relative significance of the M choices when they are examined in terms of the N decision criteria combined is a slightly different problem from the one described above. We need a scale of numbers to make comparisons because it tells us how much more important or dominant one element is over another element in terms of the criterion or quality concerning which they are compared.

4.3 Parameters Selection

In this section, we will choose the effective parameters for the supply chain management system at various levels that are useful in the Indian railway system. The AHP quantification involves the 3*3 variable, and they are accepted by various numbers of experts from various perspectives (Table 4.1).

Table 4.1: Criteria description for IR SCM

Label	Description
Integration System	Model 1
Financial Behavior	Model 2
Management Perspective	Model 3

4.4 Proposed Model

Start by collecting four individual assessments from three railway decision specialists and building a model. Four pairwise comparison matrices must be constructed using the crude AHP approach, with the consistency ratio calculated for each matrix. It's important to remember that this holds for all of the above (availability, quality of service on the railway, reliability, integration system management, and money). As a result, any pairwise comparison matrix may be used (Figure 4.2).

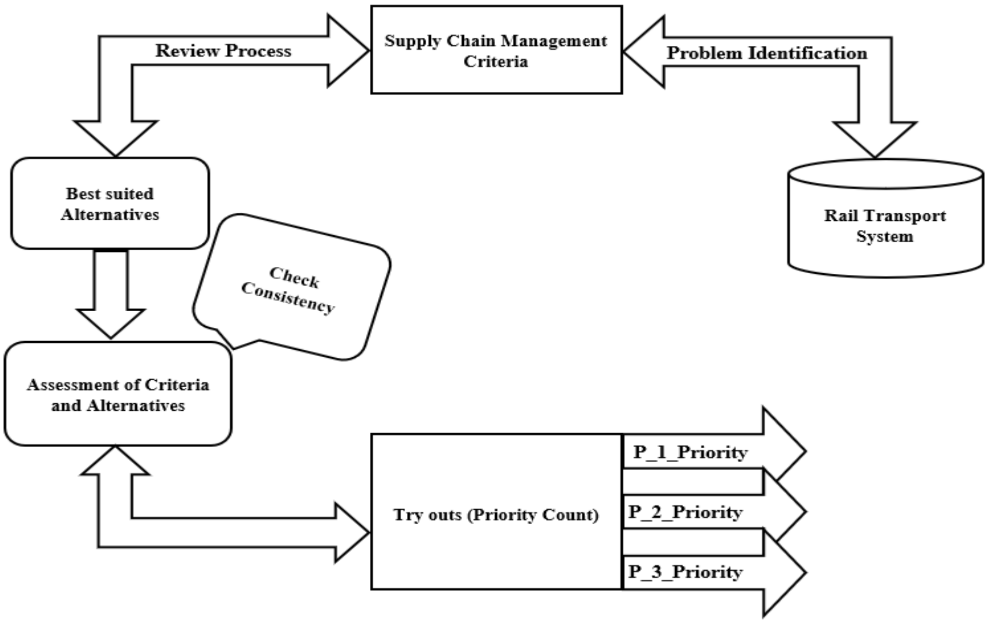

Figure 4.2: Proposed AHP model

Saaty applied the AHP technique twenty years back which is now a widely used technique for multi-attribute decision making in many fields. It is a method of prioritizing decisions that incorporates all relevant decision criteria into the decision-making process. This is accomplished through pairwise assessments of all competing objectives, which necessitates the application of subjective judgments. As a result, a scale of relative values is determined by calculating a ratio scale. The AHP procedure is divided into two stages. To begin, the design step is where a hierarchy is established; then comes the evaluation phase, which is when pairwise comparisons are made between the various options. To construct a hierarchy, an estimator must have prior experience and knowledge of the problem area, but no prior knowledge of real data is required. The uppermost node in the hierarchy symbolizes the overarching objective. If, for example, we are trying to figure out which approach can create the most accurate forecasts, it would be a good place to start. For each judgment, the overall dimension under examination is represented in terms of the perceived contribution of each option to that overall dimension. A ratio scale is derived from the produced matrix and an eigenvector technique. To do this, a normalized column average is used. A cost comparison is used to calculate the relative weights for each option, and this is done in this way. It's a way of quantifying the relative importance of each option to the common property at the level immediately above. To reach the desired outcome, this procedure is repeated for each property on a defined level. To illustrate the three techniques (Integration System, Financial Behavior, and Management Perspective) would be evaluated again in terms of quality, and weightings would be determined for each verification (Availability, Quality of Railway Service, and Reliability) on the SCM dimension. It would be necessary to compare attributes at the next level with the common attribute immediately above them in the next stage. As a result of the decomposition of the problem into machine algorithms to resolve the model dependency shown in tables 4.2 to 4.10, a large number of pairwise comparisons will need to be performed to choose the effective parameters (availability, quality of railway service, and reliability) using the AHP method. Analytics Hierarchy Process (AHP) methods frequently fail to provide consistent comparison values, particularly for problems involving many variables (such as the Integration System, Financial Behavior, and Management Perspective) and many variables (such as the Integration System) (Availability, Quality of railway service, Reliability) in Figure 4.3. The inconsistencies shown by a ratio consistency value are important when making a pairwise comparison matrix for reliability.

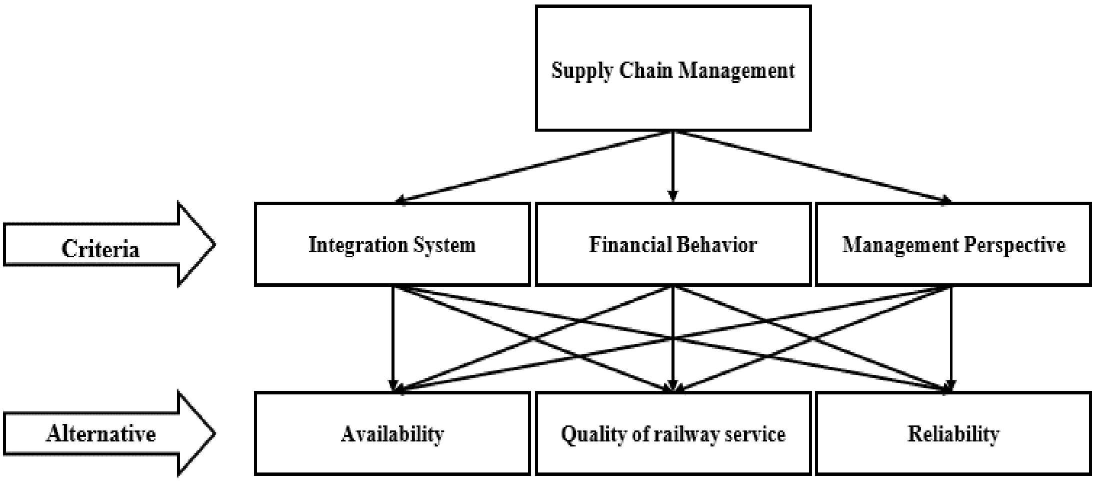

Figure 4.3: Criteria and Alternatives of IR SCM

Table 4.2: Alternative description for IR SCM

Label	Description
Availability	Impact Level 1
Quality of Railway Service	Impact Level 2
Reliability	Impact Level 3

Table 4.3: Weight for Model 1

Integration System	Availability	Quality of railway service	Reliability
Availability	1.00	0.12	0.16
Quality of railway service	8.33	1.00	0.55
Reliability	6.25	1.82	1.00

Table 4.4: Normalized matrix for Model 1

Integration System	Availability	Quality of railway service	Reliability
Availability	0.064171123	0.040841584	0.093567251
Quality of Railway Service	0.534759358	0.340346535	0.321637427
Reliability	0.401069519	0.618811881	0.584795322

Table 4.5: Index value for Model 1

Index	**Value**
Max_C_weight	0.534892241
Criteria	3
Eigenvalue	1.095928401
Consistency Index	5.300078765
Random Index	58.99
Consistency Ratio	0.089847072
Check If(CR<0.10)	TRUE

In order to evaluate the models, The AHP rating scales were applied to the criteria. Since availability, quality of railway service, and reliability require maximization and range from 0 to 1 (in this case, from 0.0042477 to 0.31280248), we used the rating scale in table 4.4. As seen in table 4.5, the Eigenvalue resulted in 1.0959 with an ideal Max_C_weight of 0.534892241. Nonetheless, two other attributes also stand out: reliability came a close second with a score of 0.312. It is possible to see the average consistency index obtained from the output of the models in the test phase. In table 4.4, the weight can be found from the output of the models in the previous observations. When compared to the inconsistency of the alternatives (which depend on availability, quality of railway service, and reliability), you can figure out the weight from this model that helped make accurate predictions.

Table 4.6: Weight for Model 2

Financial Behavior	**Availability**	**Quality of railway service**	**Reliability**
Availability	1.00	1.22	1.26
Quality of Railway Service	0.82	1.00	1.28
Reliability	0.79	0.78	1.00

Table 4.7: Normalized matrix for Model 2

Financial Behavior	Availability	Quality of railway service	Reliability
Availability	0.382655	0.406497	0.355932
Quality of Railway Service	0.313651	0.333195	0.361582
Reliability	0.303694	0.260308	0.282486

Table 4.8: Index value for Model 2

Index	Value
Max_C_weight	0.381695
CriteraCOunt	3
Eigen value	1.003758
Consistency Index	0.998121
Random Index	19.63
Consistency Ratio	0.050847
Check If (CR<0.10)	TRUE

An attempt has been made in these contributions to assign weight to SCM height impact and critically analyses the Analytic Hierarchy Process as a developed decision-making tool. The contribution highlights the application areas in each of the chosen themes. Table 4.7 is used to calculate the normalized value and the constancy index, which aids in providing SCM evaluations for the consistency of the Indian railway system. Table 4.8 shows the consistency variables in a form that provides an Eigen vector and a consistency ratio.

In Table 4.8, the weight from observation and behavior is assigned and compared to the inconsistency of the alternatives, which is dependent on availability, quality of railway service, and reliability. We can calculate this through a tree model that manages to play a positive role in correct predictions and also calculates the normalized metrics.

Table 4.9: Weight for Model 3

Management Perspective	Availability	Quality of railway service	Reliability
Availability	1.00	1.32	1.36
Quality of railway service	0.76	1.00	1.38
Reliability	0.74	0.72	1.00

Table 4.10: Normalized matrix for Model 3

Management Perspective	Availability	Quality of railway service	Reliability
Availability	0.401144083	0.43354912	0.36363636
Quality of railway service	0.303897033	0.32844631	0.36898396
Availability	0.294958885	0.23800457	0.26737968

Table 4.11: Index value for Model 3

Index	Value
Max_C_weight	0.399443
Critera Count	3
Eigen value	1.006285
Consistency Index	0.996857
Random Index	19.56
Consistency Ratio	0.050964
Check If (CR<0.10)	TRUE

In the index value for model 3 resulted in the best value with an ideal Max_C_weight of 0.399443. In Table 4.11, we can see the average consistency index that was calculated from the test phase outputs of the alternatives using normalized metrics.

4.5 Results and Discussion

Observations of the AHP method

The AHP pairwise comparison matrix has three models established which are: Integration System, Financial Behavior, and Management Perspective. The two methodologies' simulated training, validation, and testing are carried out first. However, regarding reducing CR, the integrated system behaves like a managerial viewpoint, but with superior accuracy in forecasting previously unknown inputs. Financial Behavior, on the other hand, has a much slower convergence rate. The AHP assessments for each model may be found in the final table for each model. When it is compared to the three models of the original input elements, we can say that financial behavior and management perspective have managed to play a positive role in between them (figure 4.4). Some observations and keynotes are given below.

- An evaluation study of the Analytic Hierarchy Process (AHP) and MLP approaches was also conducted while extracting the weights of criteria for models and their alternatives.
- In this evaluation, we first tried to predict the best factors of SCM through MLP algorithms with specific accuracy and thereby prevent issues in the Indian Railway system. In the second step, we used the AHP process to show how variables like precision, recall, and sensitivity depend on each other.
- In the Clarity concept, we have done the work in one segment, such as availability, quality of railway service, and reliability, based on the
- The financial behavior and management perspective gained the most weight.

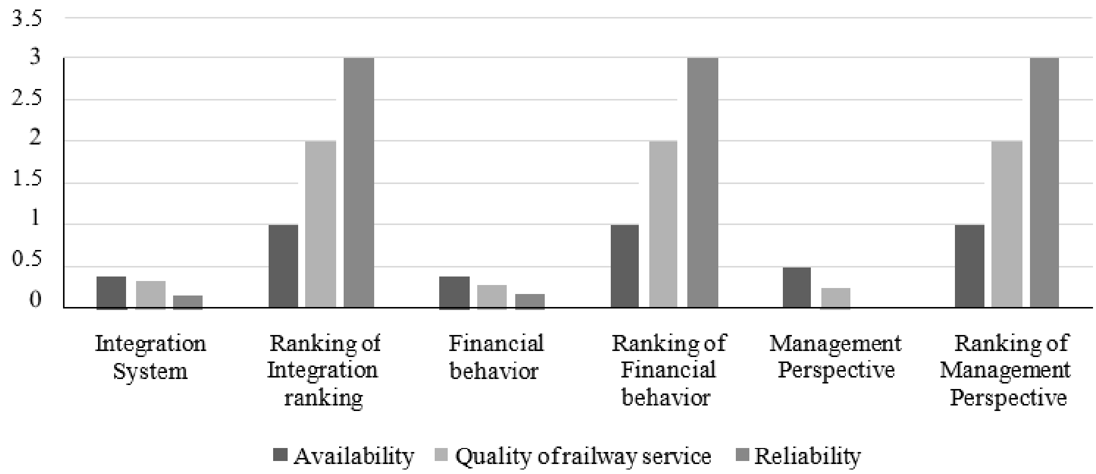

Figure 4.4: Final weight and ranking of the proposed models through the AHP method

Empirical Validation of the proposed model:

Using the TOPSIS method, the AHP index value of alternatives may be assessed (based on their resemblance to an ideal solution). MCDM issues may be solved using TOPSIS, as shown in Table 4.12. These studies demonstrate that the AHP model's results may be validated using this technique alone or in combination with others. Table 4.13 shows how TOPSIS may be used to solve MCDM issues. Studies demonstrate that this strategy may be used alone or in conjunction with other methods to address the issues. For comparison purposes, findings from the AHP approach were compared to those from the study results. TOPSIS and other approaches for solving MCDM issues are of interest to us.

Table 4.12: Assigned weight for TOPSIS method

Weightage	0.534892	0.381695	0.399443		
	Availability	**Quality of railway service**	**Reliability**	**Term**	**Fuzzy Number**
Integration System	1.4	1.59	1.79	Very Low	1,1,3
Financial behavior	3.35	4.24	5.26	Low	1,3,5
Management Perspective	5.15	6.5	7.3	Average	3,5,7
				High	5,7,9
				Very High	7,9,9

Many benefits may be gained by using the TOPSIS technique in MCDM situations. It helps in making decisions based on quantitative data rather than relying solely on subjective judgments. This can lead to more objective and rational decision outcomes. The TOPSIS technique has benefits in terms of its capacity to quickly select the best options, handle contradictory circumstances and rank the options. Next, the judgement data may be entered immediately, without the need for complex computations. For example, Table 4.13 lists TOPSIS grade and rank preferences, whereas Table 4.14 lists top-ranking conventional TOPSIS ranks. Only the first two slots of the proposed and standard TOPSIS are different. According on the relative proximity coefficient, the ranking order will change Figure 4.5 depicts the distance between the positive and negative results of the suggested validated approach, as shown by the dotted lines. A large difference (suggested model) exists between positive and negative distances. As a result, the technique guarantees an optimum ranking. Figure 4.6 compares the results of the new approach with those of the old.

Table 4.13: Normalized Matrix for TOPSIS method

	Availability	Quality of railway service	Reliability
Integration System	0.22218	0.200711	0.195117
Financial behavior	0.531646	0.535229	0.573361
Management Perspective	0.817306	0.820515	0.79573

By using the ideas behind normal distribution, we were able to normalize the decision matrix that is shown in Table 4.14 of this article. In point of fact, we illustrate the statistical standardization with the weight. The following is an explanation of the processes involved in this methodology, along with their respective outcomes on our choice matrix (refer to Figure 4.5 and 4.6).

Table 4.14: Assigned Weight

Criteria Weightage	0.534892	0.381695	0.399443		
	Availability	**Quality of railway service**	**Reliability**	**Si+**	**Si-**
Integration System	0.118842	0.07661	0.077938	0.405467165	0.239910564
Financial behavior	0.284373	0.213793	0.229025	0.243228943	0.232613897
Management Perspective	0.437171	0.327749	0.317849	0.239910564	0.405467165
V+	0.437171	0.327749	0.077938		
V-	0.118842	0.07661	0.317849		

Normal distribution converts basic values of various statistics to standard values between -3.59 and +3.59 by decreasing the mean of meter and dividing the output of this function by the standard deviation of data, as demonstrated in the formula below:

Zij is the standard value of each data point, μj is the more favorable and reasonable content of each criteria that experts of the organization have chosen, and Sx is the standard deviation of each criterion that is derived using the following formula (Figure 4.5):

$$Zj = \frac{rij - \mu j}{Sx}, \quad j = 1, 2, \dots m; i = 1, 2, \dots, n$$

$$Sx = (rij - \mu j), \quad j = 1, 2, \dots, m ; i = 1, 2, \dots, n$$

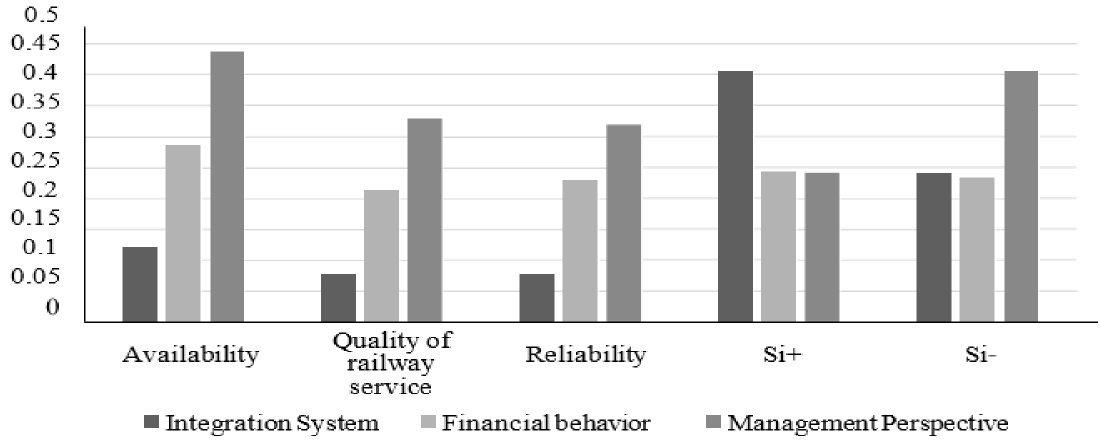

Figure 4.5: Final Criteria Ranking

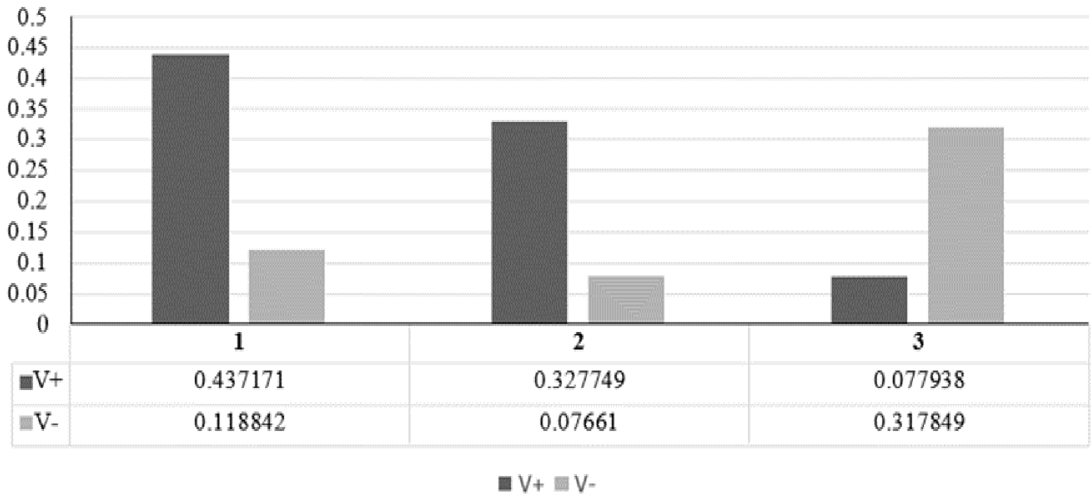

Figure 4.6: Distance significance

The group decision-makers' assessments determined the priorities of the parameters. Demonstrates the dependability of the supply chain management selection criterion. As a result, decision-makers in manufacturing firms should incorporate the preceding criteria into supply chain management. According to the AHP evaluation, the inconsistency, or CR, is 0.10. This implies that the group evaluations (accepted supply chain management parameters in the Indian railway system) are consistent. Measuring the effective parameters for the Indian railway system is not enough; they also require empirical validation through other approaches to effective performance. To accomplish this, we checked the proposed model's accuracy using the TOPSIS method. Through consistency ratio conditions, Table 4.14 support the Consistency of effective parameters. Then, using two constants (V- and V+), we used the TOPSIS approach to assess the accuracy. Its observation provided the accepted parameters, and the model is more important to the Indian Railways' supply chain management system.

4.6 Conclusions

The Analytical Hierarchy Process (AHP) and TOPSIS are useful tools that can be employed to make decisions in the classification process. The methodology in this study consists of five phases, i.e., parameter selection from expert comments, identifying the most important criteria, analysis by the AHP method; validation by the TOPSIS technique; and finally, ranking the best criteria of a high-quality proposed model. Also, sensitivity analysis ensured that the findings were consistent and trustworthy. This approach is expected to contribute significantly to the quality system of IR SCM. Furthermore, it offers a means to address complex multi-decision matrix selection problems through a statistical approach. The contribution of the chapter could be abridged as follows:

- A hierarchical model and methodological process are applied to evaluate the ranking of the parameters of the IRSCM. The ability to assign weights based on the relative relevance of each criterion and the consideration of factors such as decision complexity, subjectivity, and uncertainty are used in the selection process for IR SCMs.
- The AHP method developed the interrelationship among the parameters and evaluated the weight of all three criteria and CR value. The weight of the integrated system was the highest and the CR value of all the criteria was found to be less than 0.10, showing the consistency of the selected group of parameters.
- The TOPSIS model provided a higher criterion value for S1 and a lower criterion value for S2, S3, and all other variables combined. The final ranking order, also provided by the TOPSIS technique, showed that S1 was projected to perform better than suppliers S2 and S3.
- The AHP method results have been validated through the TOPSIS method with Si+ and Si- values. The values show that the proposed methods are highly significant and have valid parameter ranges.
- Thus, the proposed framework serves well and produced satisfactory results to improve the Indian railway system.

CHAPTER 5

BARRIERS IN RAIL TRANSPORT SUPPLY CHAIN MANAGEMENT: A MODIFIED-TOTAL INTERPRETIVE STRUCTURAL MODELLING (M-TISM) APPROACH

5.1 Introduction

Indian railways have attracted attention from suppliers, business experts, and policymakers due to their focus on transportation logistics. Recent studies in the sector highlight a similar level of interest in different strategies among suppliers in rail transport. However, the rail transport sector needs more information regarding supply chains. Access to publications in the databases is limited, creating a barrier for suppliers and the rail transport supply chain. An M-TISM, or Modified-Total Interpretive Structural Model, is used to pinpoint major supply chain administration roadblocks. By highlighting the importance of IT-enabled SCM in rail transportation, the study's discussion above gives perspective. It defines the goal and methodology of the research to effectively address these issues while acknowledging the barriers and constraints that prevent it from being implemented. By filling up these research gaps, we may achieve a deeper comprehension of the barriers facing IT-enabled supply chain management in the rail industry and accelerate the creation of practical solutions.

Lack of top management:

The lack of top management commitment in the supply chain management of Indian railway transport leads to inefficiencies in procurement, poor logistics planning, and inadequate inventory control. Without clear direction and strong leadership, critical resources may not be allocated properly, resulting in delays, disruptions, and increased operational costs. This weakens the overall performance of the railway system, affecting service quality and the timely execution of projects.

Inefficient information and technology system:

The lack of an efficient information and technology system in Indian railway transport's supply chain management leads to poor data visibility, delays in decision-making, and ineffective tracking of resources. This results in inventory mismanagement, logistical bottlenecks, and increased operational costs, ultimately undermining service efficiency and reliability.

The disinclination of the support from distributors, retailers, and dealers:

The lack of support from distributors, retailers, and dealers in the supply chain management of Indian railway transport hampers collaboration and communication. This disinclination can lead to delays in goods distribution, inventory shortages, and misalignment of supply and demand, ultimately affecting service reliability and customer satisfaction.

Lack of policy support for strategic/long-term contracting:

The lack of policy support for strategic and long-term contracting in the supply chain management of Indian railway transport results in short-term, reactive approaches to procurement. This can lead to instability in supplier relationships, inadequate resource planning, and missed opportunities for cost savings and innovation, ultimately undermining the efficiency and effectiveness of the supply chain.

Lack of IT skilled / trained manpower in field units:

The lack of IT-skilled and trained manpower in field units of Indian railway transport's supply chain management leads to ineffective use of technology, resulting in poor data management and operational inefficiencies. This skills gap hinders the implementation of modern IT solutions, limiting the ability to optimize processes and respond effectively to barriers in logistics and inventory management.

Lack of collaboration among supply chain partners:

The lack of collaboration among supply chain partners in Indian railway transport leads to fragmented communication and coordination, resulting in delays, inefficiencies, and misalignment of goals. This hampers effective resource sharing and problem-solving, ultimately affecting service delivery and overall operational performance.

Environmental Issues:

Environmental issues in the supply chain management of Indian railway transport can lead to regulatory barriers, increased operational costs, and the need for sustainable practices. Addressing these issues is crucial for minimizing the environmental impact, ensuring compliance with regulations, and improving the railway's reputation, which can ultimately enhance efficiency and long-term viability.

Natural Disasters and Weather Conditions:

Natural disasters and weather conditions play a significant role in the supply chain management of Indian railway transport by causing disruptions, delays, and damage to infrastructure. These events can hinder the timely movement of goods and passengers, necessitating effective risk management strategies and contingency plans to ensure operational resilience and minimize impact on service delivery.

Security concerns:

Security concerns in the supply chain management of Indian railway transport can lead to increased operational risks, heightened surveillance costs, and potential disruptions in services. Addressing these concerns is crucial for safeguarding assets, ensuring passenger safety, and maintaining the integrity of goods transported, ultimately impacting overall supply chain efficiency and reliability.

Lack of responsiveness:

The lack of responsiveness in the supply chain management of Indian railway transport leads to delays in decision-making and inefficiencies in addressing issues, resulting in poor service delivery and customer dissatisfaction. This inertia hampers the ability to adapt to changing demands and unforeseen disruptions, ultimately affecting operational performance and reliability.

The identified barriers are analyzed in this part using MCDM approaches. The principal methodologies employed are fuzzy MICMAC (FMICMAC) analysis and modified-total interpretive structural modeling (M-TISM). Thus, this part may be further divided into two separate components, each of which has a description that follows. In the first section, the use of the Modified-Total Interpretive Structural Modeling (M-TISM) approach is discussed. This phase consequently involves mapping out the various barriers, and creating the first and final accessibility matrices after that. The application of the fuzzy MICMAC approach is covered in the second part. Consequently, this section also covers the barrier mapping, which is done after the preliminary and final fuzzy reachability matrices are created. Additionally, the driving and dependency schematics are shown.

5.2 Modified Total Interpretive Structural Modelling (M-TISM)

The Modified-Total Interpretive Structural Modeling (M-TISM) method is an enhanced version of the Total Interpretive Structural Model (TISM) and Interpretive Structural Model (ISM), according to Sushil (2019). The Total Interpretive Structural Model (TISM) and Interpretive Structural Model (ISM) are preferred over the Modified-Total Interpretive Structural Modeling (M-TISM) approach because it offer a conceptualized model with a well-described hierarchy of components. Moreover, the methods of TISM and ISM examine transitivity relations independently, which occasionally necessitates an iterative process. This situation is challenging. According to Kamble et al. (2019), the Modified-Total Interpretive Structural Modeling (M-TISM) technique may efficiently be used to accomplish reachability and transitivity assessments in a single phase. We shall go over the stages of the Modified-Total Interpretive Structural Modeling (M-TISM) methodology in this chapter.

Step 1: We identify all barriers during this stage through extensive research and expert input. We selected a group of thirty-two experts for this study, twelve of whom have over fifteen years of experience in the transportation sector of Indian railways. In addition, the remaining eight suppliers boast extensive experience spanning over a decade, while nine have accumulated more than five years of valuable expertise. Furthermore, three suppliers have built a solid foundation with over a year of experience.

Step 2: This step examines the connection between different barriers. This connection is known as the contextual relationship. We are interested in understanding the impact that one barrier has on another. The interconnections among all recognized barriers are depicted.

Step 3: This step analyses the connection between different factors and investigates the underlying reasons for their relationship. In addition, the M-TISM technique addresses questions of "why" and "how" that conventional TISM and ISM methods often overlook.

Step 4: It entails simultaneously performing a transitivity check and developing a reachability matrix. We need to investigate the relationship between these barriers to entering the matrix. In the matrix, we designate a "Y" for a positive association and an "N" for no relationship when there is a connection. Next, ascertain transitivity by determining that A will link to C if A connects to B and B connects to C. Lastly, replace the "Y" and "N" in Table 5.1 values with 1 and 0 respectively in Table 5.2. Table 5.3 displays the reachability matrix based on the provided data. It contains either "Y" or "N." entries. The complete reachability matrix is displayed in Table 5.3.

Table 5.1: Structural self-interaction matrix

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
B1	-	N	Y	N	N	Y	Y	N	N	Y
B2	N	-	N	N	N	Y	N	N	Y	Y
B3	Y	N	-	N	N	N	Y	N	Y	Y
B4	N	Y	Y	-	N	N	N	N	Y	N
B5	N	N	N	N	-	N	N	N	Y	N
B6	Y	Y	N	N	N	-	N	N	N	Y
B7	N	N	N	N	N	N	-	Y	N	N
B8	N	N	N	N	N	N	Y	-	N	N
B9	Y	N	Y	N	N	N	N	N	-	N
B10	N	N	Y	N	N	N	N	N	N	-

Table 5.2: Conversion into binary numbers

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
B1	0	0	1	0	0	1	1	0	0	1
B2	0	0	0	0	0	1	0	0	1	1
B3	1	0	0	0	0	0	1	0	1	1
B4	0	1	1	0	0	0	0	0	1	0
B5	0	0	0	0	0	0	0	0	1	0
B6	1	1	0	0	0	0	0	0	0	1
B7	0	0	0	0	0	0	0	1	0	0
B8	0	0	0	0	0	0	1	0	0	0
B9	1	0	1	0	0	0	0	0	0	0
B10	0	0	1	0	0	0	0	0	0	0

Table 5.3: Transitivity Checks (Final reachability matrix)

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
B1	1	1*	1	0	0	1	1	1*	1*	1
B2	1*	1	1*	0	0	1	0	0	1	1
B3	1	0	1	0	0	1*	1	1*	1	1
B4	1*	1	1	1	0	1*	0	0	1	1*
B5	1*	0	1*	0	1	0	0	0	1	0
B6	1	1	1*	0	0	1	1*	0	1*	1
B7	0	0	0	0	0	0	1	1	0	0
B8	0	0	0	0	0	0	1	1	0	0
B9	1	0	1	0	0	1*	1*	0	1	1*
B10	1*	0	1	0	0	0	1*	0	1*	1

Step 5: Partitioning levels and developing a model

This stage breaks all of the barriers into impact-level categories. The model then goes through more development. Similar technique to that of ISM and TISM procedures is used in the categorization of barriers. Following the computation of each barriers cumulative deriving and reliance power score, the barriers were divided into several tiers. The reachability set and precursor sets must be determined throughout this procedure. The reachability set includes the barrier as well as any other impediments that may have an impact on it, whereas the antecedent set contains the barrier and any potential hazards. When these two comparable elements are combined, an intersecting set is produced. Finding the level involves exactly matching the intersection set with the reachability set, then eliminating those values. The above process is repeated until all required decisions have been made. The height of each impediment is ascertained and recorded in Table 5.4 following the completion of the procedures necessary in the ultimate accessible matrix.

Table 5.4: Level Partitioning

Barrier Code	Reachability set	Antecedent set	Intersection Set	Level
B1	1,2,3,6,7,8,9,10	1,2,3,4,5,6,9, 10	1,2,3,6,9,10	3
B2	1,2,3,6,9,10	1,2,4,6	1,2,6	4
B3	1,3,6,7,8,9,10	1,2,3,4,5,6,9,10	1,3,6,9,10	4
B4	1,2,3,4,6,9,10	4	4	5
B5	1,3,5,9	5	5	5
B6	1,2,3,6,7,9,10	1,2,3,4,6,9	1,2,3,6,9	2
B7	7,9	1,3,6,7,8,9,10	7,9	1
B8	7,8	1,3,7,8	7,8	1
B9	1,3,6,7,9,10	1,2,3,4,5,6,9,10	1,3,6,9,10	2
B10	1,3,7,9,10	1,2,3,4,6,9,10	1,3,9,10	4

Table 5.5: Classification of barriers into different levels

Barrier code	Name of Barriers	Level Partitioning
B4	Lack of policy support for strategic/long-term contracting	5
B5	Lack of IT skilled/trained manpower in field units	5
B2	Inefficient information and technology system	4
B3	The disinclination of the support from distributors, retailers, and dealers	4
B10	Lack of responsiveness	4
B1	Lack of top management Commitment	3
B6	Lack of collaboration among supply chain partners	2
B9	Security concerns	2
B7	Environmental Issues	1
B8	Natural Disasters and Weather Conditions	1

Plotting the model is the next step that comes after level partitioning. This exercise examines every barrier in Table 5.5 that may come up when handling a supply chain. Two barriers are located at level 5 at the bottom and two barriers are located at level 1 at the top. The levels are arranged in order of significance, level 1 being the least important and level 5 being the most crucial. As per this rule, the most significant barriers are the absence of governmental support for strategic or long-term contracting (B4) and the shortage of IT-trained or qualified personnel in field units (B5). The least important barriers are lack of response (B7) and security concerns (B8) as shown if Figure 5.1.

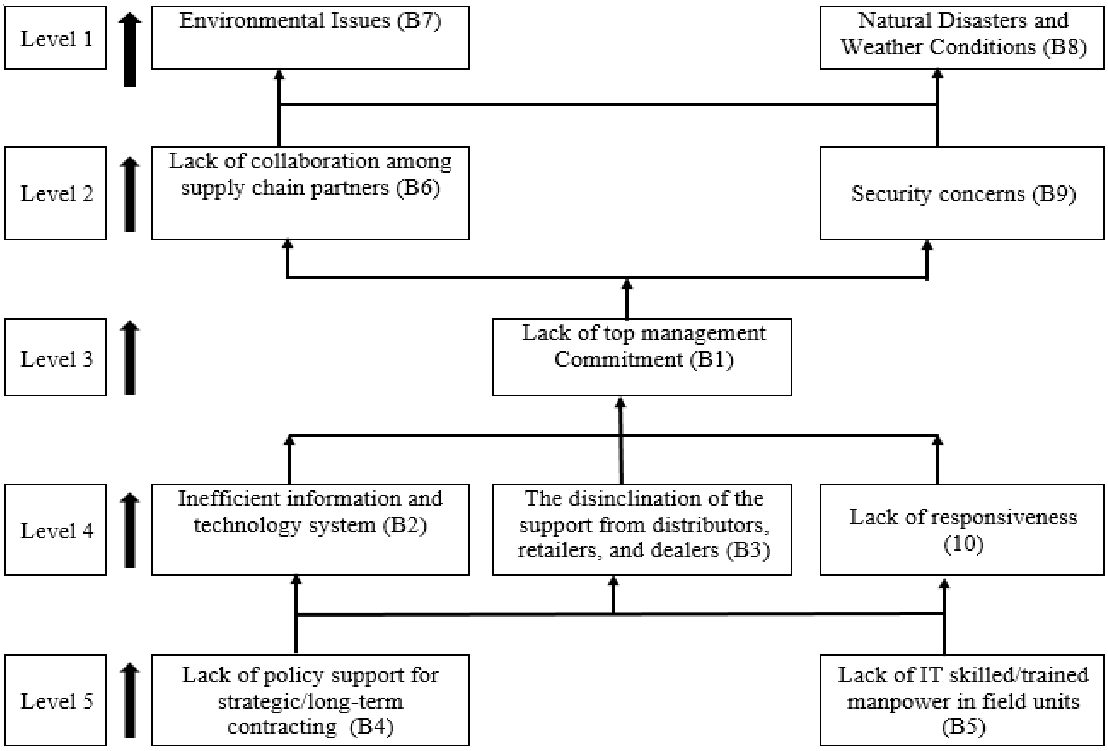

Figure 5.1: Level partitioning model

5.3 Fuzzy-MICMAC (FMICMAC) Analysis

The M-TISM technique uses the numbers 0 and 1 to indicate how the two barriers are related to each other. However, the FMICMAC (Fuzzy-MICMAC) technique offers the opportunity to delve deeper into this relationship. The group can be divided into very strong, moderate, low strong, and weak categories.

This ambiguity and weakness in the decision-making cycle are addressed by the fuzzy theory. Zadeh (1965). The opinions of experts are sought to translate the language judgments into imprecise numerical values. The authors use FMICMAC over the conventional MICMAC method because it offers the flexibility to scale difficulties into four values (0.3, 0.5, 0.7, and 0.9). Nevertheless, traditional MICMAC is divided into two categories (i.e., 0 and 1). Therefore, expert opinions are more accurately documented in FMICMAC than in conventional MICMAC. Normal multiplication takes place in the conventional MICMAC approach, whereas fuzzy multiplication happens in the FMICMAC method.

The fuzzy matrix multiplication process is used in FMICMAC analysis. According to Pathidar et al. (2017), this multiplication method differs significantly from traditional matrix multiplication, Sarkar D. et al (2015). Khan U. et al. (2012) established the fuzzy multiplication rule, which states that the product of two fuzzy matrices is also a fuzzy matrix. Below is a description of this multiplication process using the fuzzy multiplication equation, which is represented by the matrices A and B. Below is a representation of equation (1)'s fuzzy multiplication equation.

$$AB = Max\{Min(a_{ij}, b_{ij})\}\text{..................(i)}$$

Where,

$$A = (a_{ij})$$

$$B = (b_{ij})$$

Using the FDRM as the base matrix, the procedure is first started. After several multiplicities, the matrix is reiterated. Until the dependent power and driving factors settle, this procedure is repeated. Identification of the items is done by adding the rows and columns of the final fuzzy accessibility matrix. Just as it was done previously, this procedure delivers the elements' driving power and reliance.

Table 5.6: Fuzzy direct reachability matrix (FDRM)

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**
B1	0	0.5	0.5	0.1	0.3	0.7	0.1	0.5	0.3	0.9
B2	0.7	0	0.7	0.1	0.1	0.9	0.1	0.3	0.5	0.7
B3	0.7	0.5	0	0.3	0.1	0.5	0.1	0.3	0.5	0.1
B4	0.5	0.9	0.3	0	0.3	0.7	0.1	0.5	0.7	0.3
B5	0.5	0.5	0.3	0.1	0	0.7	0.3	0.1	0.5	0.9
B6	0.1	0.1	0.7	0.1	0.1	0	0.1	0.1	0.1	0.3
B7	0.3	0.1	0.1	0.1	0	0.1	0	0.1	0.1	0.3
B8	0.5	0.1	0.3	0.1	0.1	0.3	0.3	0	0.1	0.1
B9	0.1	0.3	0.3	0.1	0.1	0.1	0.1	0.3	0	0.7
B10	0.3	0.7	0.5	0.3	0.1	0.7	0.1	0.1	0.9	0

The table 5.6 displays the fuzzy reachability matrix that was produced. Fuzzy stabilized matrix values are shown in Table 5.7.

Table 5.7: Fuzzy stabilized matrix

	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**	**B10**	**Driving Power**
B1	0.5	0.7	0.7	0.3	0.1	0.7	0.3	0.3	0.9	0.5	5
B2	0.7	0.7	0.7	0.3	0.3	0.7	0.3	0.5	0.7	0.7	5.6
B3	0.5	0.5	0.5	0.1	0.3	0.7	0.3	0.5	0.5	0.7	4.6
B4	0.7	0.7	0.7	0.3	0.3	0.9	0.3	0.5	0.7	0.7	5.8
B5	0.5	0.7	0.7	0.3	0.3	0.7	0.1	0.5	0.9	0.5	5.2
B6	0.7	0.5	0.3	0.3	0.1	0.5	0.1	0.3	0.5	0.1	3.4
B7	0.3	0.3	0.3	0.3	0.3	0.3	0.1	0.3	0.3	0.3	2.8
B8	0.3	0.5	0.5	0.3	0.3	0.5	0.1	0.5	0.3	0.5	3.8
B9	0.3	0.7	0.5	0.3	0.1	0.7	0.3	0.3	0.7	0.3	4.2
B10	0.7	0.5	0.7	0.3	0.3	0.7	0.1	0.3	0.5	0.7	4.8
Dependence Power	5.2	5.8	5.6	2.8	2.4	6.4	2	4	6	5	**45.2**

5.4 Findings from fuzzy MICMAC analysis

Following the fuzzy MICMAC analysis, the output provides the driving force and a binary representation of each element's dependence. Each element is divided into four sections according to the driving force and ramifications of these dependencies. These components are shown in figure 5.2 below in the quadrants denoted I, II, III, and IV. These quadrants are known as autonomous, dependent, linkage, and independent components, depending on the respective values.

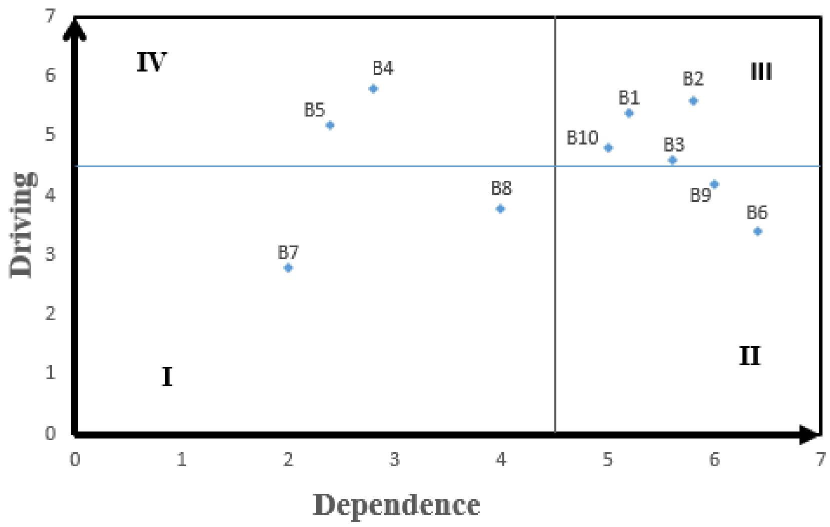

Figure 5.2: Driving & dependence power diagram

Autonomous elements: These barriers have little reliance and little driving force. This category contains four barriers. There are a few key linkages among these hurdles.

Barrier number 7 (environmental issues) and barrier 8 (natural disasters and weather conditions) are among the barriers.

Dependent elements: All of these barriers are highly dependent but have little driving force. Barrier number 6 (Lack of collaboration among supply chain partners), and barrier number 9 (Security concerns) are among them.

Linkage elements: Both significant dependence and a powerful motivating factor are present in these barriers. Among them are barrier number 1 (disinclination of senior management to commit), number 2 (inefficient information and technology system), number 3 (disinclination of distributors, merchants, and dealers to assist), and number 10 (lack of reactivity).

Independent elements: These barriers are all quite independent and have a strong driving force. Barrier number 4 (Lack of policy support for strategic/long-term contracting), and barrier number 5 (Lack of IT skilled/trained manpower in field units) are among them. They are independent elements. However, they are quite powerful drivers. So that they can affect the other components. Two distinct kinds of barriers are present in this area.

5.5 Results

Determining the barriers to supply chain management adoption in the rail transportation sector is the goal of this study. In supply chain management, professional perspectives are taken into account while tackling these issues. Decimals between 0 and 1 are used to describe their perspective, along with binary digits and fuzzy numbers. Numerous factors must be carefully considered while scaling FMICMAC analysis utilizing the Modified-Total Interpretive Structural Modeling (M-TISM) technique. The purpose of this work is to evaluate the importance of the barriers. By applying the Modified-Total Interpretive Structural Modeling technique, the impediments are divided into five categories, ranging from the most critical (level 5) to the most reliable (level 1). Following that, a fuzzy MICMAC analysis is carried out. By considering the generating and dependent power characteristics of the barriers this exercise attempts to divide the barriers into four divisions. Through a thorough analysis of each factor's criticality, this method enables barriers to be divided into four different quadrants: autonomous, dependent, linkage, and independent factors. In order to drive barriers, independent and linking parts are essential. The Modified-Total Interpretive Structural Modeling model's levels 4 and 5 (i.e., B2, B3, B4, B5, and B10 barriers) are where all independent and linking elements are situated, according to the results. The Fuzzy MICMAC technique therefore supports the result of the Modified-Total Interpretive Structural Modeling approach.

5.6 Conclusions

The study identifies barriers to implementing supply chain management in the rail transport sector. Focusing on the professional perspective Using Modified Total Interpretation Structure Modeling (M-TISM) and Fuzzy MICMAC analysis, barriers are ranked from critical to manageable. At the same time, they are categorized into four different quadrants based on their generation characteristics and dependent effect characteristics. This estimation helps understand which factors act as independent and interacting components that drive barriers. The results indicate that the most important barriers are at levels 4 and 5 in the M-TISM model and confirm the findings through Fuzzy MICMAC analysis. The next chapter analyzes the delivery of the supply chain management system. And provide additional insights into operational efficiency and potential improvements.

CHAPTER 6

ANALYSIS OF SUPPLY CHAIN PERFORMANCE IN INDIAN RAIL TRANSPORT

6.1 Introduction

Supply chain management deliverables are important measures of an organization's operational efficiency. In the case of Indian Railways, effective supply chain management directly affects the ability to provide services such as cost efficiency and overall efficiency. This chapter analyses the effectiveness of supply chain management in Indian railway transport. It focuses on key variables and applies advanced statistical tools and modeling techniques. The analysis assesses the impact of various factors contributing to the increase in the performance of the supply chain in Indian railway transport.

6.2 Profile of the Respondents

In Table 6.1, the respondents consist of professionals from various roles within the rail industry, providing insights from different functional areas and levels of experience. Their feedback helps ensure the study reflects various perspectives on supply chain management practices and challenges.

Table 6.1: Profile of the respondents

		F	N %	Min	Max	Mean	Standard Deviation
Position in the Industry	CEO	25	17.2%				
	Sr. Manager	26	17.9%				
	Manager	42	29.0%				
	Member of Board	7	4.8%				
	Director	44	30.3%				
	Other	1	0.7%				
	Total	**145**	**100.0%**	1	5	3	1

		F	N %	Min	Max	Mean	Standard Deviation
Supply Chain activity in your company is related to the following products:	Automotive Parts	53	36.6%				
	Electrical Parts	65	44.8%				
	Electronics Parts	20	13.8%				
	Consumer Goods	6	4.1%				
	Other	1	0.7%				
	Total	**145**	**100.0%**	1	5	2	1
Functional area	Materials	104	71.7%				
	Operations	6	4.1%				
	Technical	30	20.7%				
	Marketing	5	3.4%				
	Total	**145**	**100.0%**	1	4	2	1
Your association in years with the current organization	Less than 5 years	13	9.0%				
	5-10 years	41	28.3%				
	10-15 years	62	42.8%				
	More than 15 years	29	20.0%				
	Total	**145**	**100.0%**	1	4	3	1
Does your Industry have ISO 14001/50001 certification?	Yes	134	92.4%				
	No	11	7.6%				
	Total	**145**	**100.0%**	1	2	1	0

Position in the Industry

Directors make up the largest group of respondents, accounting for 30.3% of the total respondents, followed closely by managers, who make up 29.0%. The smallest group is those who selected 'Other,' representing just 0.7% of the respondents. The data for this category ranges from a minimum position of 1 to a maximum of 6, with a mean of 3 and a standard deviation of 1, indicating a moderate spread around the mean.

Supply Chain Activity Related Products

Electrical parts are the most common product type related to supply chain activities in the respondents' companies, at 44.8%. The 'Other' products category has the least number of respondents, at 0.7%. Responses range from 1 to 5, with an average of 2 and a standard deviation of 1, suggesting a slight concentration towards the middle categories.

Functional Area

Materials is the predominant functional area, with a significant 71.7% of respondents involved in this function. Marketing is the least represented functional area, accounting for only 3.4%. The responses range from 1 to 4, with a mean of 2 and a standard deviation of 1, indicating a moderate spread with a focus on the Materials area.

Years of Association with Current Organization

The majority of respondents have been with their current organization for 10–15 years, representing 42.8%. The least represented group is those with less than 5 years of association, at 9.0%. The number of years of association ranges from 1 to 4, with an average of 3 and a standard deviation of 1, indicating a fairly even distribution among the middle categories.

ISO 14001/50001 Certification

A vast majority of the industries have ISO 14001/50001 certification, with 92.4% affirming this. Only 7.6% of the respondents indicated that their industry does not have this certification. The responses are binary (1 for 'Yes' and 2 for 'No'), with a mean of 1 and a standard deviation of 0, showing a strong consensus towards certification.

Table 6.2: Descriptive analysis

Statements	Very Low		Low		Average		High		Very High								
	F	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**F**	**%**	**SD**	**Mean**	**Min**	**Max**	**Mean**	**Skewness**	**Kurtosis**
Developing strong, long-term, collaborative relationships with suppliers	7	4.8%	1	.7%	10	6.9%	86	59.3%	41	28.3%	.904	4.06	1	5	4.06	-1.771	4.245
Using intermediaries to develop fresh suppliers and logistics infrastructure.	9	6.2%	2	1.4%	20	13.8%	76	52.4%	38	26.2%	1.006	3.91	1	5	3.91	-1.393	2.157
Freely exchanging information with suppliers and customers.	6	4.1%	6	4.1%	9	6.2%	86	59.3%	38	26.2%	.932	3.99	1	5	3.99	-1.554	2.933
Having a clear customer and shareholder focus	8	5.5%	4	2.8%	12	8.3%	80	55.2%	41	28.3%	.989	3.98	1	5	3.98	-1.529	2.584
Supporting the acquisition and implementation of appropriate information systems	4	2.8%	4	2.8%	15	10.3%	81	55.9%	41	28.3%	.865	4.04	1	5	4.04	-1.386	2.936
Benchmarking and continual improvement	4	2.8%	1	.7%	14	9.7%	85	58.6%	41	28.3%	.807	4.09	1	5	4.09	-1.531	4.293
Designs of specialized engineering related to the upgrading locomotive power supply systems	20	13.8%	24	16.6%	30	20.7%	36	24.8%	35	24.1%	1.364	3.29	1	5	3.29	-.289	-1.128
Enhance optimal systems at a reasonable cost and receive the highest profit.	8	5.5%	11	7.6%	36	24.8%	59	40.7%	31	21.4%	1.071	3.65	1	5	3.65	-.737	.162
Optimization to achieve maximum energy and minimum consumption.	11	7.6%	11	7.6%	35	24.1%	60	41.4%	28	19.3%	1.116	3.57	1	5	3.57	-.761	.063
Introduction of mathematical algorithms for planning and scheduling	18	12.4%	18	12.4%	21	14.5%	51	35.2%	37	25.5%	1.329	3.49	1	5	3.49	-.617	-.793

Statements	Very Low		Low		Average		High		Very High								
	F	%	F	%	F	%	F	%	F	%	SD	Mean	Min	Max	Mean	Skewness	Kurtosis
Improvement of specialized approaches to the safety assessment of railway systems in a dynamic framework.	11	7.6%	17	11.7%	28	19.3%	50	34.5%	39	26.9%	1.214	3.61	1	5	3.61	-.659	-.474
Development of a specialized method for analyzing the performance errors of operators in digital rail control rooms.	6	4.1%	3	2.1%	10	6.9%	87	60.0%	39	26.9%	.893	4.03	1	5	4.03	-1.670	3.830
Improve information sharing.	6	4.1%	15	10.3%	19	13.1%	84	57.9%	21	14.5%	.984	3.68	1	5	3.68	-1.055	.793
Decision synchronization	18	12.4%	17	11.7%	36	24.8%	52	35.9%	22	15.2%	1.225	3.30	1	5	3.30	-.494	-.665
Improve incentive alignment	14	9.7%	16	11.0%	39	26.9%	53	36.6%	23	15.9%	1.167	3.38	1	5	3.38	-.541	-.434
Improves the supply chain configuration.	7	4.8%	9	6.2%	30	20.7%	61	42.1%	38	26.2%	1.055	3.79	1	5	3.79	-.891	.483
Improve the enabling technology.	11	7.6%	18	12.4%	38	26.2%	40	27.6%	38	26.2%	1.220	3.52	1	5	3.52	-.464	-.678
Enhanced level of collaboration	8	5.5%	11	7.6%	38	26.2%	49	33.8%	39	26.9%	1.115	3.69	1	5	3.69	-.670	-.102
Improve service effectiveness for suppliers.	5	3.4%	0	0.0%	18	12.4%	83	57.2%	39	26.9%	.841	4.04	1	5	4.04	-1.501	3.924
Improve operational efficiency.	1	.7%	0	0.0%	20	13.8%	83	57.2%	41	28.3%	.686	4.12	1	5	4.12	-.687	1.884
Improve service effectiveness for the consignee.	2	1.4%	0	0.0%	21	14.5%	81	55.9%	41	28.3%	.739	4.10	1	5	4.10	-.993	2.799
Improve supplier performance.	2	1.4%	0	0.0%	22	15.2%	82	56.6%	39	26.9%	.737	4.08	1	5	4.08	-.966	2.758
Reduce Supply chain responsiveness	6	4.1%	0	0.0%	41	28.3%	59	40.7%	39	26.9%	.955	3.86	1	5	3.86	-.885	1.213
Reduce responsiveness to customers	2	1.4%	0	0.0%	31	21.4%	73	50.3%	39	26.9%	.782	4.01	1	5	4.01	-.732	1.488

Descriptive analysis at the management level (Table 6.2).

Top Management Commitment:

Developing Strong, Long-Term, Collaborative Relationships with Suppliers: The majority of respondents, 87.6% (86 high + 41 very high), believe that this is an important factor, with a mean score of 4.06 indicating a strong agreement. The low standard deviation of 0.904 suggests consensus among respondents. The data is skewed to the left (-1.771), indicating more responses at the higher end, and has a positive kurtosis (4.245), suggesting a peak distribution.

Using intermediaries to develop new suppliers and logistics infrastructure is a popular strategy. A high percentage, 78.6% (76 high + 38 very high), supports the use of intermediaries. The mean of 3.91 and a higher standard deviation of 1.006 show a slightly more varied opinion. The distribution is negatively skewed (-1.393), with more responses on the higher side and a moderate kurtosis (2.157).

Freely Exchanging Information with Suppliers and Customers: This statement is supported by 85.5% (86 high + 38 very high), with a mean of 3.99 and a standard deviation of 0.932, indicating slight variability. The skewness (-1.554) and kurtosis (2.933) show a distribution leaning towards higher values with a slight peak.

Having a Clear Focus on Customers and Shareholders: A total of 83.5% (80 high + 41 very high) agree with this focus. The average is 3.98, with a standard deviation of 0.989. The distribution is skewed to the left (-1.529) and has a moderate kurtosis (2.584), reflecting more higher-end responses.

Supporting the Acquisition and Implementation of Appropriate Information Systems: An 84.2% majority (81 high + 41 very high) supports this, with a mean of 4.04. The low standard deviation of 0.865 indicates strong agreement. The skewness (-1.386) and kurtosis (2.936) suggest a slightly peaked distribution with higher scores.

Benchmarking and Continual Improvement: This has 86.9% support (85 high + 41 very high) with a mean of 4.09 and a low standard deviation of 0.807, showing consistency in responses. The skewness (-1.531) and high kurtosis (4.293) suggest a strong consensus towards higher values.

Supply chain Management Rail Transport:

Specialized Engineering Designs Related to Upgrading Locomotive Power Supply Systems: This statement is supported by only 48.9% (36 high + 35 very high). The mean of 3.29 and a high standard deviation of 1.364 indicate significant variability in responses. The skewness is slightly negative (-0.289), and the kurtosis is negative (-1.128), indicating a flat distribution.

Enhance optimal systems at a reasonable cost and receive the highest profit: Here, 62.1% (59 high + 31 very high) support this idea, with a mean of 3.65 and a standard deviation of 1.071, indicating varied responses. The skewness is negative (-0.737), and the kurtosis is slightly positive (0.162).

Optimization to Achieve Maximum Energy and Minimum Consumption: This statement received 60.7% support (60 high + 28 very high), with a mean of 3.57 and a standard deviation of 1.116. The distribution is slightly skewed to the left (-0.761) with a small positive kurtosis (0.063).

Introduction of Mathematical Algorithms for Planning and Scheduling: With 60.7% (51 high + 37 very high) support, the mean is 3.49, and the standard deviation is 1.329, suggesting some disagreement. The skewness (-0.617) and kurtosis (-0.793) indicate a slightly left-skewed and flat distribution.

Improvement of Specialized Approaches to the Safety Assessment of Railway Systems in a Dynamic Framework: This statement has 61.4% support (50 high + 39 very high), with a mean of 3.61 and a standard deviation of 1.214. The distribution is negatively skewed (-0.659) and slightly flat (-0.474).

Developing a Specialized Method for Analyzing Operator Performance Errors in Digital Rail Control Rooms: With a mean of 4.03, a significant 86.9% of respondents (87 high and 39 very high) agree with this. The standard deviation of 0.893 indicates less variability, and the skewness (-1.670) and kurtosis (3.830) suggest a peaked distribution towards higher values.

Supply Chain Collaboration:

Improve Information Sharing: With 72.4% support (84 high + 21 very high), the mean is 3.68, and the standard deviation is 0.984. The distribution is left-skewed (-1.055) and has a slight peak (0.793).

Decision Synchronization: A lower 51.1% (52 high + 22 very high) supports this, with a mean of 3.30 and a standard deviation of 1.225, indicating diverse opinions. The skewness (-0.494) and kurtosis (-0.665) show a slightly skewed and flat distribution.

Improve Incentive Alignment: With 52.5% (53 high + 23 very high) agreement, the mean is 3.38 and the standard deviation is 1.167, showing variability in responses. The skewness (-0.541) and kurtosis (-0.434) indicate a slightly flat and left-skewed distribution.

Improves the Supply Chain Configuration: This statement has 68.3% (61 high + 38 very high) support, a mean of 3.79, and a standard deviation of 1.055. The distribution is skewed to the left (-0.891) with a slight peak (0.483).

Improve the Enabling Technology: A total of 53.8% (40 high + 38 very high) support this statement. The mean is 3.52, and the standard deviation is 1.220, indicating diverse opinions. The skewness (-0.464) and kurtosis (-0.678) show a slightly skewed and flat distribution.

Enhanced Level of Collaboration: With 60.7% (49 high + 39 very high) agreement, the mean is 3.69, and the standard deviation is 1.115. The distribution is slightly skewed to the left (-0.670) and relatively flat (-0.102).

Supply Chain Performance:

Improve Service Effectiveness for Suppliers: This statement is supported by a high 84.1% (83 high + 39 very high), with a mean of 4.04 and a standard deviation of 0.841. The skewness (-1.501) and kurtosis (3.924) suggest a strong consensus towards higher values.

Improve Operational Efficiency: This statement has 85.5% (83 high + 41 very high) agreement, a mean of 4.12, and a low standard deviation of 0.686, indicating strong consensus. The skewness (-0.687) and kurtosis (1.884) suggest a peaked distribution towards higher values.

Improve Service Effectiveness for the Consignee: With 84.2% (81 high + 41 very high) agreement, the mean is 4.10 and the standard deviation is 0.739. The distribution is skewed to the left (-0.993) and slightly peaked (2.799).

Improve Supplier Performance: This statement has an 83.5% (82 high + 39 very high) agreement, a mean of 4.08, and a low standard deviation of 0.737. The skewness (-0.966) and kurtosis (2.758) suggest a distribution leaning towards higher values.

Reduce Supply Chain Responsiveness: With 67.6% (59 high + 39 very high) agreement, the mean is 3.86 and the standard deviation is 0.955, showing some variability. The skewness (-0.885) and kurtosis (1.213) indicate a distribution with more responses on the higher end.

Reduce Responsiveness to Customers: Finally, this statement has 77.2% (73 high + 39 very high) agreement, a mean of 4.01, and a standard deviation of 0.782. The skewness (-0.732) and kurtosis (1.488) suggest a slightly peaked distribution towards higher values.

6.3 Model-Based Analysis

6.3.1 Reflective Component in Measurement Model

A reflecting component is included in the measuring model that is being used in the present study. In order to ensure that the structural model is as streamlined as ever, some indications have been left out. According to Hair et al. (2012), the purpose of this elimination procedure is to eliminate both inner and outside collinearity difficulties, which will ultimately lead to the conclusion that discriminant validity has been established. As a result, the outer model only contains those indicators with values that are expected to be greater than sixty percent.

6.3.2 Algorithm Settings

To conduct data analysis, we apply Smart PLS 3.0 and utilize an algorithm setting specifically designed for the weighting scheme required by the structural model. This piece of software is used to process the raw data in order to make it easier to include standardized data for the indicators (Hair et al., 2012). In addition, a stop condition of (1.10-5) is chosen for the algorithm to converge, and the maximum number of iterations that may be performed is the limit of 300.

6.3.3 Bootstrapping: Algorithm Settings

A non-parametric procedure is carried out because it does not presume any distribution. The bootstrapping approach is used to determine whether the coefficients of interest are significant. The following protocols are going to be implemented: The sample size for this research consists of 145 original observations that are considered legitimate. According to the rule of thumb, 5,000 bootstrap samples are accounted for while the SMARTPLS algorithm is being executed. Secondly, the number of cases is equal to the number of valid observations (145). When doing a two-tailed test with a significance level of 0.05 and a critical t value of 1.96, empirical t values are compared with critical t values. This is done in order to determine the results significance. Sign Change Option: The empirical t-values are evaluated without the 'no sign change' option.

6.3.4 Measurement Model Assessment: Reliability

A combination of Cronbach's alpha and composite reliability (CR) is used in order to evaluate the reliability of the measurement model that is utilized in SMARTPLS. Because it does not treat all indicators as equal contributors to the latent variables and does not underestimate internal consistency, composite reliability is considered to be superior to Cronbach's alpha. This is because it avoids the tendency to inflate internal consistency reliability as the number of items in the scale increases. Inside the measurement model, an analysis of the R-square statistic is performed to determine the covariance of the endogenous latent variable on the exogenous latent variable. This allows for the evaluation of the model's fit to the initial data.

6.3.5 R-Square Values

R-square values might have a different threshold than others. In the study conducted by Hair et al. (2012), the researchers determined that an R-square value of 0.75, 0.50, and 0.25 is regarded as high, moderate, and weak, respectively. Chin (1998) identifies R-square values of 0.67, 0.33, and 0.19 as significant, moderate, and weak, whereas Cohen (1998) suggests values of 0.26, 0.13, and 0.02, and Falk and Miller (1992) propose a threshold of 0.10. Other research presents alternative thresholds. Chin (1998) argues that one threshold is 0.67, 0.33, and 0.19.

The fact that R -square is 0.708 suggests that the exogenous variables (Supply Chain Collaboration (SCC), Supply Chain Management Rail Transport (SCMRT), and Top Management Commitment (TMC)) are responsible for explaining a certain amount of the variation in the endogenous variable Supply Chain Performance (SCP). The findings, which include outer loadings and R-square values, are shown in the measurement model Figure 6.1.

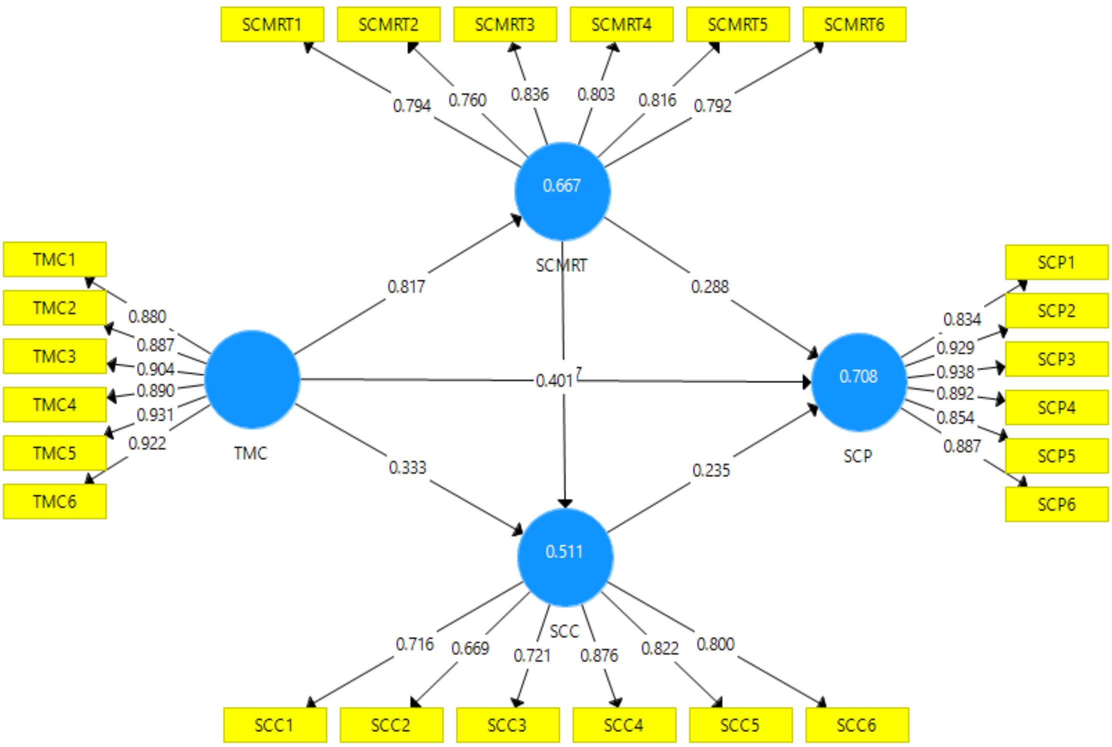

Figure 6.1: The results of Measurement Model

Source: Field Survey Data

6.3.6 Internal Consistency Reliability

Cronbach's alpha is often regarded as a conservative measure of internal consistency dependability in the context of PLS-SEM, which stands for partial least squares structural equation modeling. Composite Reliability (CR), which is also known as internal reliability, is preferred by previous studies due to the constraints that it has (Hair et al., 2012). The reliability coefficient is considered to be preferable than Cronbach's alpha since it has the tendency to enhance the dependability value with the inclusion of additional indicators. There should be a threshold value for internal reliability that is equal to or higher than 0.70 when employing Composite Reliability (CR), according to Heisser (2012). However, according to Daskalakis and Mantas (2008), there are research that claim that the values must be more than 0.80 in order for the internal reliability to be regarded satisfactory. Significant insights into the reliability and validity of the variables that were used to examine consumer purchasing behavior in relation to infant items are provided by the findings of the reflective measurement models, which are included in Table. The consistency and stability of the constructs have been evaluated with the use of important measures such as Cronbach's alpha and composite reliability (CR).

Cronbach's alpha is a measure of internal consistency that is extensively used. It ensures that a construct's indicators measure the same underlying notion in a reliable manner. Cronbach's alpha values for all of the constructs in this investigation are higher than the acceptable threshold of 0.70, which indicates that the constructs have a high level of reliability (Hair et al., 2010). There is a correlation between the six indicators (SCC1 to SCC6) and the notion of supply chain collaboration, as shown by the fact that the construct of supply chain collaboration (SCC) has a Cronbach's alpha value of 0.864. The outer loadings of these indicators range from 0.669 to 0.876, and the reliability values vary from 0.448 to 0.767. In a similar vein, the Supply Chain Management Rail Transport (SCMRT) construct has a Cronbach's alpha value of 0.888, which indicates that its six indicators (SCMRT1 to SCMRT6) have a high degree of internal consistency. The outer loadings for these indicators vary from 0.760 to 0.836, and the reliability values for these indicators range from 0.578 to 0.699 during the course of the study. The Supply Chain Performance (SCP) construct has an even higher Cronbach's alpha value of 0.947, indicating that its six indicators (SCP1 to SCP6) have outstanding internal consistency with one another. These indicators' outer loads range from 0.834 to 0.938, while their dependability values range from 0.696 to 0.880. Last but not least, the Top Management Commitment (TMC) construct has a Cronbach's alpha value of 0.954, which indicates that its six indications (TMC1 to TMC6) have a very high degree of internal consistency with one another. These indicators' outer loads range from 0.880 to 0.931, while their dependability values range from 0.774 to 0.867. According to Nunnally and Bernstein (1994), the high Cronbach's alpha values across all constructs indicate that there is a strong internal consistency and reliability in the measurement of the ideas that are supposed to be measured. It is common practice to regard Cronbach's alpha as a conservative measure of internal consistency and dependability when it comes to PLS-SEM, which stands for partial least squares structural equation modeling. According to previous studies, the use of composite reliability (CR), also known as internal reliability (Hair et al., 2012), is recommended due to its constraints. CR is considered superior to Cronbach's alpha because it has a tendency to increase the dependability value with the inclusion of additional indications. It is recommended that the threshold value for internal reliability, which is determined by composite reliability (CR), be equal to or more than 0.70 (Henseler, 2012). Nevertheless, there are studies that contend that the values must be more than 0.80 in order for the internal reliability to be regarded as satisfactory (Daskalakis & Mantas, 2008). The table shows the results of the reflective measurement models. These results give us important information about how reliable and valid the constructs were that were used in the study on how people buy baby items. In order to evaluate the consistency and stability of the constructs, important measures such as Cronbach's alpha and composite reliability (CR) have been used.

Rho_A, which is sometimes referred to as Dijkstra-Henseler's rho, is a measure of composite reliability that solves several shortcomings of Cronbach's alpha. These problems include Cronbach's alpha's sensitivity to the number of items on a scale, as well as its assumption of tau-equivalence. When rho_A values are higher, it indicates that the constructions have a higher level of internal consistency and dependability. The rho_A values for all of the constructs shown in the table are higher than the acceptable threshold of 0.70, indicating a high level of dependability. To be more specific, the rho_A value for Supply Chain Collaboration (SCC) is 0.892, which indicates that the indicators (SCC1 to SCC6) consistently assess the underlying construct of supply chain collaboration with a high degree of dependability. Supply Chain Management Rail Transport (SCMRT) demonstrates a rho_A value of 0.891, which indicates that the indicators (SCMRT1 to SCMRT6) accurately reflect the construct of rail transport in supply chain management. Supply Chain Performance (SCP) has a rho_A value of 0.949, which indicates that its indicators (SCP1 to SCP6) have a very high degree of internal consistency with one another. The fact that the top management commitment (TMC) has a rho_A value of 0.955 demonstrates that the indicators (TMC1 to TMC6) are able to accurately quantify the commitment of top management in relation to supply chain management. The durability of the reflective measurement models that were used in this investigation is shown by these rho_A values, which are consistently higher than 0.70. The study's results are more credible due to their emphasis on assessing the constructs with a high level of reliability and internal consistency.

Composite reliability, often known as CR, is a measurement that is used in reflective measurement models to evaluate the internal consistency and reliability of a collection of indicators intended to measure a certain construct. A comprehensive evaluation of the indicators' ability to accurately measure the underlying concept is carried out. It has been determined that CR values that are more than 0.70 are deemed acceptable, which indicates that the construct accurately represents the variation in the indicators (Hair et al., 2019). The fact that the CR values for all of the constructs in the table that has been presented are much higher than the acceptable threshold of 0.70 demonstrates high reliability: A CR of 0.897 indicates that there is a high degree of internal consistency across the six indicators that make up Supply Chain Collaboration (SCC), which range from SCC1 to SCC6. Supply Chain Management Rail Transport (SCMRT) shows a CR of 0.914, which indicates that its six indicators (SCMRT1 to SCMRT6) have a high degree of dependability. Supply Chain Performance (SCP) has a CR of 0.958, which indicates that it has strong internal consistency across all six of its indicators (SCP1 to SCP6). With a coefficient of determination (CR) of 0.963, Top Management Commitment (TMC) demonstrates an exceptional level of dependability across all six of its indicators (TMC1 to TMC6). The measurement model used in this study is valid because the CR values are high. This means that the constructs are measured accurately by their own indicators (Henseler et al., 2015).

The **average variation extracted (AVE)** is a metric that is used to evaluate the amount of variation that is captured by the indicators of a construct in comparison to the amount of variance that happens as a result of measurement error. If the AVE value is greater than 0.50, it means that the construct explains more than half of the variation in its indicators, which is typically considered satisfactory. The AVE values for each construct in this study are greater than 0.50, indicating adequate convergent validity. According to Fornell and Larcker (1981), the average variance extracted (AVE) for Supply Chain Collaboration (SCC) is 0.593. This indicates that the concept itself accounts for more than 59% of the variation in SCC indicators, showing that appropriate convergent validity is present between the construct and the indicators. Similar to the previous example, the average variance extracted (AVE) for Supply Chain Management Rail Transport (SCMRT) is 0.641, which indicates that the construct accounts for 64.1% of the variation in its indicators. With a value of 0.792 for the average variance extracted (AVE), the Supply Chain Performance (SCP) construct has an exceptionally high degree of convergent validity. Because the construct captures 79.2% of indicator variation. Last but not least, the Top Management Commitment

(TMC) construct has an average variance extracted (AVE) of 0.814, which indicates that it is responsible for 81.4% of the variation in what it measures. Hair et al. (2017) These AVE values, together with high composite reliability (CR) and Cronbach's alpha values, provide evidence that the constructs being evaluated in this research are being measured with high reliability and validity. This demonstrates that the measurement models are robust enough to be used for further analysis.

The **outer loadings** that are shown in the table are a representation of the degree to which the correlations between each indicator and the constructs that relate to it are strong enough. Its outer loading, also called factor loading, measures how well each indicator explains the construct it assesses. According to Hair et al. (2010), loadings that are more than 0.70 are regarded as high, despite the fact that values as low as 0.40 may be acceptable in exploratory research. For the Supply Chain Collaboration (SCC) build, the outside loadings might vary anywhere from 0.669 to 0.876 at any one time. There is a strong indication that the indicators SCC4 (0.876) and SCC5 (0.822) are the most reflective of the SCC construct, as they have the largest loadings at the moment. However, despite having the lowest loading, SCC2 (0.669) still contributes to the construct assessment. When it comes to Supply Chain Management Rail Transport (SCMRT), the outside loadings might range anywhere from 0.760 to 0.836. A loading of 0.836 suggests that SCMRT3 is the most reliable indicator for SCMRT. This is because it has the highest load. Other indicators have significant loadings, suggesting their importance to the construct. When it comes to Supply Chain Performance (SCP), the outside loadings are very robust, with values ranging from 0.834 to 0.938. Because SCP3 (0.938) and SCP2 (0.929) have the highest loadings, it may be inferred that these indicators are extremely adept at accurately describing the SCP construct. On the other hand, the construct known as Top Management Commitment (TMC) has outer loadings that range from 0.880 to 0.931. The loadings of TMC5 (0.931) and TMC6 (0.922) are the greatest, which indicates that they have a good alignment with the build itself. Due to the significant loadings that are present across all indicators for TMC, it can be inferred that these indicators, when taken as a whole, provide a reliable evaluation of top management commitment.

6.3.7 Discriminant Validity

When evaluating the uniqueness of notions, discriminant validity is an extremely important factor (Wasko & Faraj, 2005). Specifically, it evaluates the degree to which each latent variable in a model can be distinguished from the others. The squared correlations across variables are compared with their respective Average Variance Extracted (AVE), as stated by Chin (1998). This comparison is used to determine the model's discriminant validity. An in-depth evaluation of the measurement model is often the first step in this analysis, which is followed by an assessment of the structural model. The method is in accordance with the recommendations that were established by Hair et al. (2012), whose software makes it easier to conduct an exhaustive examination of the answers to the data in PLS-SEM. For the purpose of conducting a thorough evaluation of discriminant validity across constructs, it is usual practice to make use of methods such as the Fornell-Larcker Criterion, Cross Loading, and the Heterotrait-Monotrait Ratio (HTMT).

Fornell-Larcker Criterion: In 1981, the Fornell-Larcker Criterion was developed to evaluate the uniqueness of variables. This was accomplished by comparing the square root of the average variance extracted (AVE) with the correlations that exist between different constructs. With this criteria, understanding the unique characteristics of each variable in the research is made easier. The following table provides an illustration of the discriminant validity of the latent variables. It demonstrates that the square root of the AVE values is higher than the correlations with the other latent variables. This conclusion, by confirming that each variable has appropriate discriminant validity, ensures that the variables in the measurement model are sufficiently different from one another. The findings of the Fornell-Larcker Criterion (1981), which was used to evaluate the discriminant validity of the constructs investigated in this research, are presented in the table. According to this criteria, in order to verify the discriminant validity of each construct, the square root of the average variance extracted (AVE) for each construct should be greater than the correlations that it has with other constructs. In the table, the diagonal components represent the square roots of the AVE values for each construct. In order to show discriminant validity, it is necessary for these square roots to be greater than the off-diagonal correlation coefficients. Each diagonal value is greater than the equivalent off-diagonal values, indicating that each construct has more variance with its own indicators than with others. This is because the diagonal values are higher than the off-diagonal values. This provides evidence that the constructs, as a whole, possess adequate discriminant validity.

The items that are diagonal in the table 6.3 indicate the square root of the average variance extracted (AVE) for each construct, while the ones that are off-diagonal represent the correlations that exist between the three constructs. A value of 0.770 is assigned to the square root of the AVE for Supply Chain Collaboration (SCC). When compared to its relationships with other constructs, this value is significantly higher. The SCC correlates with Supply Chain Management Rail Transport (SCMRT) at sixty-eight percent, Supply Chain Performance (SCP) at seven point four percent, and Top Management Commitment (TMC) at seven point seven percent. Because the SCC is more strongly related to its own measures than it is to those of other constructs, it has a high level of discriminant validity. The square root of the AVE for Supply Chain Management Rail Transport (SCMRT) is equal to 0.800. Additionally, this number is larger than its correlations with other constructs, which are 0.778 with SCP and 0.817 with TMC, respectively. The fact that the correlation with SCC is 0.689 is further evidence that SCMRT is able to differentiate itself well from other constructions. There is a higher correlation between Supply Chain Performance (SCP) and TMC (0.795) than with other constructs (0.704 for SCC, 0.778 for SCMRT, and 0.890 for TMC). This is shown by the square root of the average variance extracted (AVE). The fact that the AVE value is so high suggests that the SCP has remarkable discriminant validity, meaning that it is more closely connected to its own indicators than it is to those of other constructs. Top Management Commitment (TMC) has the greatest square root of AVE value, which is 0.902. This value is higher than its correlations with SCC (0.673), SCMRT (0.817), and SCP (0.795). This provides more evidence that TMC is a unique construct that is differentiated from the others. It can be seen from the table that all of the constructions satisfy the Fornell-Larcker criterion, which is evidence of their high level of discriminant validity. To ensure that each construct is unique within the model, it is important to note that each construct is more closely connected to its measurements than it is to the measurements of other constructs.

Table 6.3: Discriminant validity by Fornell-Larcker Criterion (1981)

Constructs	SCC	SCMRT	SCP	TMC
Supply Chain Collaboration (SCC)	0.77			
Supply Chain Management Rail Transport (SCMRT)	0.689	0.8		
Supply Chain Performance (SCP)	0.704	0.778	0.89	
Top Management Commitment (TMC)	0.673	0.817	0.795	0.902

Cross-loading method

To determine whether or not the indicators and constructs in the research have discriminant validity, the cross-loading approach is used. In the context of this discussion, discriminant validity is established when an indicator has larger outer loadings on its specific concept in comparison to its cross-loadings on other constructs. In addition to its cross-loadings on other constructions, the table shows each indicator's outer loadings on its construct.

The table 6.4 shows discriminant validity when the cross-loading method is used to compare the loadings of indicators on different constructs with their loadings on the same constructs. This method is used to demonstrate discriminant validity. To demonstrate appropriate discriminant validity, an indicator must load more strongly on its associated concept than it does on any other constructs. SCC stands for supply chain collaboration, and the indicators SCC1 through SCC6 have the largest loadings on SCC when compared to other constructions. An example of this would be the fact that SCC1 is loaded to 0.716 on SCC, which is greater than its loadings on SCMRT (0.377), SCP (0.432), and TMC at 0.440. In a similar vein, SCC4 is loaded at 0.876 on SCC, which is much higher than its loadings on SCMRT (0.614), SCP (0.674), and TMC (0.599). This trend demonstrates that SCC indicators are unique from other indicators. SCMRT stands for supply chain management rail transport, and the indicators SCMRT1 through SCMRT6 have the greatest loadings on SCMRT. For example, SCMRT1 has a loading of 0.794 on SCMRT, which is much higher than SCC (0.542), SCP (0.604), and TMC (0.564 as well). The loading on SCMRT3 is 0.836, which is greater than the loadings on SCC (0.569), SCP (0.601), and TMC (0.652). This indicates that SCMRT3 exhibits a pattern that is comparable to the one above.

Table 6.4: Discriminant validity by Cross Loading Method

Indicators	**SCC**	**SCMRT**	**SCP**	**TMC**
SCC1	**0.716**	0.377	0.432	0.440
SCC2	**0.669**	0.418	0.323	0.358
SCC3	**0.721**	0.404	0.368	0.419
SCC4	**0.876**	0.614	0.674	0.599
SCC5	**0.822**	0.647	0.628	0.575
SCC6	**0.800**	0.616	0.670	0.626
SCMRT1	0.542	**0.794**	0.604	0.564
SCMRT2	0.505	**0.760**	0.576	0.584
SCMRT3	0.569	**0.836**	0.601	0.652
SCMRT4	0.505	**0.803**	0.615	0.614
SCMRT5	0.546	**0.816**	0.646	0.637
SCMRT6	0.621	**0.792**	0.677	0.828
SCP1	0.595	0.720	**0.834**	0.769
SCP2	0.647	0.703	**0.929**	0.765
SCP3	0.638	0.732	**0.938**	0.753
SCP4	0.611	0.660	**0.892**	0.689
SCP5	0.617	0.634	**0.854**	0.619
SCP6	0.648	0.693	**0.887**	0.628
TMC1	0.611	0.701	0.665	**0.880**
TMC2	0.644	0.761	0.679	**0.887**
TMC3	0.571	0.725	0.689	**0.904**
TMC4	0.591	0.754	0.711	**0.890**
TMC5	0.598	0.732	0.771	**0.931**
TMC6	0.629	0.746	0.781	**0.922**

This suggests that the SCMRT has a high degree of discriminant validity. Indicators SCP1 to SCP6 rely heavily on Supply Chain Performance (SCP), which is the most important metric. For example, SCP2 has a loading of 0.929 on SCP, which is much higher than its loadings on SCC (0.647), SCMRT (0.703), and TMC (0.765). This pattern is followed by SCP3, which has a loading of 0.938 on SCP, higher than its loadings on SCC (0.638), SCMRT (0.732), and TMC (0.753). This exemplifies the special characteristics that distinguish SCP indicators. When it comes to Top Management Commitment (TMC), the indicators TMC1 through TMC6 have the greatest loadings on average. For example, TMC1 has a loading of 0.880 on TMC, which is significantly higher than its loadings on SCC (0.611), SCMRT (0.701), and SCP (0.665). In a similar manner, TMC5, which is loaded to 0.931 on TMC, surpasses its loadings on SCC (0.598), SCMRT (0.732), and SCP (0.771). This demonstrates that TMC indicators have a high degree of discriminant validity overall. The cross-loading approach shows that every indication loads more on its own build than on any other. Within the model framework, this lends support to the discriminant validity of the constructs Supply Chain Collaboration (SCC), Supply Chain Management Rail Transport (SCMRT), Supply Chain Performance (SCP), and Top Management Commitment (TMC).

Heterotrait-Monotrait Ratio (HTMT) method

This research makes use of the heterotrait-monotrait ratio (HTMT) approach, which was introduced by Henseler, Ringle, and Sarstedt (2015). The purpose of this method is to examine the discriminant validity across constructs (Netyemar et al., 2003). This method is used in two different ways: as a criteria and as a statistical test. It is recommended by Gold et al. (2001) that the HTMT value should preferably be equal to or lower than 0.90 in order to validate the discriminant validity model. To establish discriminant validity, researchers compare the HTMT value obtained with this threshold. If the result is lower than 0.90, then discriminant validity exists. A threshold value of 0.90 was used for this investigation to determine the discriminant validity of the HTMT. To determine the degree of differentiation between the various constructs, a statistical test is performed in which empirical data are evaluated against predetermined criteria. If the computed HTMT value is lower than the advised threshold, this suggests that there is adequate discriminant validity between the constructs being examined. This technique offers a solid foundation for guaranteeing that every construct in the model is unique and appropriately reflects the latent variable that it is supposed to represent.

In the following table 6.5, the heterotrait-monotrait ratio (HTMT) approach is used to investigate the discriminant validity of various notions. This technique evaluates whether or not the constructions are sufficiently different from one another. In particular, the HTMT ratio is a method for determining the degree of correlation between several constructs in comparison to the correlation that exists within the same construct. Confirmation of discriminant validity occurs when the HTMT ratios are lower than a certain threshold, which is commonly considered to be 0.85 or 0.90. This indicates that the constructs in question are not highly linked with one another. An HTMT score of 0.754 is associated with supply chain performance (SCP), while a value of 0.717 is associated with top management commitment (TMC). Supply Chain Management Rail Transport (SCMRT) uses both of these metrics. The fact that both scores are lower than the usually accepted criterion of 0.85 indicates that the SCMRT continues to retain its discriminant validity in comparison to the SCP and TMC, since it does not have an excessive correlation with these constructs. In the case of supply chain performance (SCP), the HTMT ratio is 0.739 when using SCMRT, whereas it is 0.832 for using TMC. When compared to the ratio with TMC, which is extremely near the top limit but is still within an acceptable range, the ratio with SCMRT is lower than the threshold of acceptable values. This suggests that SCP is capable of effectively distinguishing between SCMRT and SCP and has adequate discriminant validity in comparison to TMC. During the study, the Top Management Commitment (TMC) demonstrated HTMT ratios of 0.877 with SCP and 0.717 with SCMRT. The ratio with SCMRT is well below the permitted range, but the ratio with SCP, although greater, is still below the threshold amount. Given this, TMC appears to differ from SCMRT and SCP. However, the connection with SCP is getting close to the top limit, which indicates that there is a need for careful analysis of construct overlap. The HTMT ratios shown in the table provide evidence that the constructs, as a whole, indicate a high level of discriminant validity, with all of the values continuously remaining below the crucial threshold. This provides evidence that the constructs are sufficiently diverse from one another, which in turn lends support to the validity of the measurement model.

Table 6.5: Discriminant validity by Hetrotrait- Monotrait Ratio (HTMT) ratio method

Constructs	SCC	SCMRT	SCP
Supply Chain Management Rail Transport (SCMRT)	0.754		
Supply Chain Performance (SCP)	0.739	0.843	
Top Management Commitment (TMC)	0.717	0.877	0.832

6.4 Model Fit Analysis

While determining whether or not the structural and measurement models are adequate, the evaluation of model fitness is an extremely important factor to consider (Henseler et al., 2012). It is helpful in identifying any possible misspecifications, as stated by Dijkstra and Henseler (2015). The standardized root mean squared residual (SRMR) is an important metric that was used for this research. A lower number, such as the 0.063 that was reported, suggests that the model fits the data more accurately. According to Hensler et al. (2012), this result is lower than the commonly recognized criterion of 0.08, which indicates that the model has an adequate level of fit. Further evidence that the model is adequate in terms of fitting the data is provided by indicators such as Root Mean Square Error of Approximation (RMSEA) and Rms Theta values that are near zero. The overall fitness of the model in properly capturing the connections among the variables that are being studied is evaluated and confirmed with the help of these metrics combined. In order to analyze the performance of both the saturated model and the estimated model, the table 6.6 presents and overview of the model fit for each of them, utilizing multiple fit indices to evaluate their respective performance.

Table 6.6: Model Fit

	Saturated Model	Estimated Model
SRMR	0.079	0.079
d_ULS	1.865	1.865
d_G	1.277	1.277
Chi-Square	945.395	945.395
NFI	0.750	0.750
rms Theta	0.193	

SRMR, which stands for "Standardized Root Mean Square Residual," has a value of 0.079 for both the saturated model and the estimated model. The SRMR calculates the standard deviation of the mean difference between the observed and anticipated correlations. According to Hu and Bentler (1999), a number that is lower than 0.08 is typically deemed to be acceptable, which indicates that the model effectively fits the data. Consequently, both models exhibit a satisfactory level of fit with regard to SRMR.

The squared Euclidean distance, or d_ULS, has a value of 1.865 for both models combined. Using this metric, the difference between the measured distances and the distances suggested by the model is evaluated. Although particular threshold values for d_ULS might vary, lower values seem to indicate a better match between the model and the data. Using this criteria, both models' consistent values indicate that they match the data similarly.

In a similar vein, both models have a value of 1.277 for d_G, which stands for geodesic distance. The difference between the actual distances and the distances that were predicted by the model is what d_G represents. As is the case with d_ULS, smaller values are desirable; nevertheless, if both models have the same value, this indicates that the fit is consistent.

The Chi-Square statistic reveals that the saturated model and the estimated model both have a Chi-Square value of 945.395. This statistic assesses the model's overall fit by comparing the observed covariance matrix to the covariance matrix suggested by the model. It is important to note that the Chi-Square value is sensitive to the size of the sample, and high values are often seen in larger samples. However, a lower Chi-Square value suggests a better match. The fact that both models have the same value indicates that they match the Chi-Square distribution similarly.

According to the Normed Fit Index (NFI), the NFI value for both models is 0.750. When comparing the fit of the model to the fit of a null model, the National Fit Index (NFI) uses values that are closer to 1 to indicate a better match. Given that values normally range from 0 to 1, with higher values reflecting a better match, an NFI of 0.750 indicates that the fit is moderate rather than excellent.

rms Theta: The value of rms Theta is stated to be 0.193. The disparity between the observed and model-implied correlation matrices is evaluated using this metric. It is desirable to have lower numbers since they indicate a better match. On the other hand, the interpretation of this statistic is highly dependent on the context being considered, since there is no comparison value or threshold.

According to the fit indices, the saturated model and the estimated model both have a similar fit to one another. The SRMR and d_ULS indices provide an indication of strong fit, while the Chi-Square and NFI indices imply that the fit is moderate. Because the models all provide the same values for the majority of the indices, it can be concluded that they are equally successful in fitting the data.

6.5 Summary of Reflective Measurement Model

With the assistance of SMARTPLS, the reflective measurement model was used to determine the reliability and validity of both constructs and indicators. Both the reliability and validity of the findings are deemed acceptable, as shown in the table 6.7.

Table 6.7: Results summary of Reflective measurement models

Constructs	Indicators	Outer Loadings	Indicator reliability	Cronbach's Alpha	rho_A	CR	AVE
Supply Chain Collaboration (SCC)	SCC1	0.716	0.513	0.864	0.892	0.897	0.593
	SCC2	0.669	0.448				
	SCC3	0.721	0.52				
	SCC4	0.876	0.767				
	SCC5	0.822	0.676				
	SCC6	0.8	0.64				
Supply Chain Management Rail Transport (SCMRT)	SCMRT1	0.794	0.63	0.888	0.891	0.914	0.641
	SCMRT2	0.76	0.578				
	SCMRT3	0.836	0.699				
	SCMRT4	0.803	0.645				
	SCMRT5	0.816	0.666				
	SCMRT6	0.792	0.627				
Supply Chain Performance (SCP)	SCP1	0.834	0.696	0.947	0.949	0.958	0.792
	SCP2	0.929	0.863				
	SCP3	0.938	0.88				
	SCP4	0.892	0.796				
	SCP5	0.854	0.729				
	SCP6	0.887	0.787				
Top Management Commitment (TMC)	TMC1	0.88	0.774	0.954	0.955	0.963	0.814
	TMC2	0.887	0.787				
	TMC3	0.904	0.817				
	TMC4	0.89	0.792				
	TMC5	0.931	0.867				
	TMC6	0.922	0.85				

The discriminant validity test that was performed on the constructs also demonstrates that all of the values satisfy the threshold conditions that were established beforehand. In light of these results, it can be concluded that the measurement model has effectively achieved reliability in its measurements and validity in its constructs. This substantiates the robustness and correctness of the model in terms of capturing and discriminating between the latent variables that are being investigated.

6.6 Structural Model

PL-SEM was used as the methodology for the evaluation of the structural model, and it was carried out in accordance with the protocols that were proposed by Hair et al. (2014). An analysis of path coefficients was done to find out how strong and important the links were between the variables after the collinearity test was done to make sure they were not related to each other negatively or positively. Additionally, the calculation of the effect size of R-square for the endogenous construct was carried out in order to determine the percentage of variation that was explained. In the next step, the predictive significance of the model was evaluated using Q-square, and blindfolding techniques were used to confirm the model's capacity to make accurate predictions. The use of an all-encompassing technique ensures a thorough examination of the structural model, with a particular emphasis on the statistical significance as well as the practical relevance of the connections that are included within the framework being researched.

6.6.1 Assessment of Collinearity

The variance inflation factor (VIF) analysis, which is a common approach that was advocated by Hair et al. (2012), was used in order to evaluate the degrees of collinearity that were present in the structural modeling. The VIF values for all constructs were below 5.00, indicating no collinearity or multicollinearity. As a result of this finding, the structural modeling process was allowed to continue without any issues related to inter-variable correlations that may have affected the results' dependability.

For the purpose of the inner model evaluation, the variance inflation factor (VIF) values that were derived for exogenous constructions are shown in the table. If the VIF result is less than 5.00, it indicates that the degrees of collinearity among the variables are acceptable. Based on the Variance Inflation Factor (VIF) results, which were used to check for collinearity between the exogenous factors in the inner model of the research project on how people buy things for babies, it was discovered that any such levels were usually low.

In the following table, you will find information on how to evaluate collinearity among exogenous constructs in the inner model using the variance inflation factor (VIF) values available. When it comes to structural equation modeling, collinearity is an issue since it has the potential to exaggerate standard errors and lead to conclusions that are deceptive. The variance inflation factor (VIF) values are used to determine the extent to which an estimated regression coefficient's variance expands as a result of collinearity with other variables.

The coefficient of determination (VIF) values for each construct are presented in the table, which assists in determining the degree of multicollinearity. When compared to comparable constructions, the value inflation factor (VIF) for supply chain collaboration (SCC) is found to be 2.046. The fact that the VIF is relatively low indicates that the SCC does not have a large degree of collinearity with the other constructs in the model. SCMRT, which stands for Supply Chain Management Rail Transport, has VIF scores of 3.002 and 3.357, respectively. There is a correlation between the first value and its collinearity with SCC, while the second value represents its collinearity with SCP. Because both of these numbers are lower than the criterion commonly used, which is either 5 or 10, it can be concluded that SCMRT does not display problematic levels of collinearity with the other constructs. Because there are no reported VIF values in the table, it may be inferred that the collinearity of Supply Chain Performance (SCP) with other constructs is either not a problem or was not evaluated in this particular context. Top Management Commitment (TMC) exhibits VIF values of 3.002 when collinear with SCC, 1.000 when collinear with SCMRT, and 3.229 when collinear between SCP and SCMRT. The VIF of 1.000 with SCMRT indicates that this construct has no collinearity. On the other hand, the values of 3.002 and 3.229 for SCC and SCP, respectively, are still below the threshold, indicating that the degrees of collinearity are manageable. According to the VIF results shown in the table, the collinearity between the exogenous constructions is within the permissible ranges. In order to guarantee accurate estimates for the connections being investigated, none of the constructs display a significant degree of collinearity, which could potentially affect the model's findings.

Table 6.8: Evaluating Collinearity for exogenous constructs through VIF inner model

Constructs	**SCC**	**SCMRT**	**SCP**	**TMC**
Supply Chain Collaboration (SCC)			2.046	
Supply Chain Management Rail Transport (SCMRT)	3.002		3.357	
Supply Chain Performance (SCP)				
Top Management Commitment (TMC)	3.002	1.000	3.229	

In the following table 6.8, the variance inflation factor (VIF) values are presented for the purpose of determining whether or not the exogenous constructs in the outer model exhibit collinearity. We use the variance inflation factor (VIF) to determine if each construct's indicators are significantly associated, which may indicate multicollinearity issues. A VIF value greater than five to ten indicates the presence of a potential multicollinearity problem. This suggests that the indicators are not sufficiently different, which may inflate the coefficient standard errors.

The VIF values for the Supply Chain Collaboration (SCC) indicators range from 1.796 to 3.053, with the average being 3.053. To be more specific, the VIF for SCC1 is 1.796, while the VIF for SCC2 is 1.939, SCC3 is 2.112, SCC4 is 3.053, SCC5 is 2.386, and SCC6 is valued at 1.827. Because these values are lower than the generally accepted threshold of 5, it may be concluded that multicollinearity is not a serious problem for SCC indicators. Indicators of Supply Chain Management Rail Transport (SCMRT) have VIF values that range from 1.856 to 3.453. The SCMRT1 indicator is 2.149, the SCMRT2 indicator is 2.233, the SCMRT3 indicator is 2.624, the SCMRT4 indicator is 3.347, the SCMRT5 indicator is 3.453, and the SCMRT6 indicator is 1.856. All of the VIF values are much lower than the threshold of 5, which indicates that there are no significant multicollinearity concerns among the SCMRT indicators. On the other hand, the VIF values for Supply Chain Performance (SCP) indicators might range anywhere from 2.481 to 4.361. SCP1 has a VIF of 2.481, SCP2 has a VIF of 3.817, SCP3 has a VIF of 4.361, SCP4 has a VIF of 3.791, SCP5 has a VIF of 3.115, and SCP6 has a VIF of 3.632. Despite the fact that these values are lower than 5, SCP3 is closer to the threshold, which indicates that it needs to be watched; nonetheless, it does not suggest that there is significant multicollinearity. The VIF values displayed by Top Management Commitment (TMC) indicators range from 3.575 to 4.590. TMC1 has a value of 3.772, TMC2 has a value of 3.873, TMC3 has a value of 4.590, TMC4 has a value of 4.099, TMC5 has a value of 3.575, and TMC6 has a value of 4.304. As a result, it can be concluded that there are no significant multicollinearity concerns affecting the TMC indicators, since all of these values are lower than 5. As can be seen from the VIF values in the table, multicollinearity does not appear to be a significant issue for the exogenous constructions that are included in the outer model. All of the indicators' results are lower than the usually recognized threshold of 5, indicating that the constructs are sufficiently separate and do not display problematic levels of collinearity.

We used the variance inflation factor (VIF) analysis, which is a common method backed up by Hair et al. (2012), to check how much collinearity there was in the structural modeling. The VIF values for all constructs were below 5.00, indicating no collinearity or multicollinearity. As a result of this finding, the structural modeling process was allowed to continue without any issues related to inter-variable correlations that may have affected the results' dependability.

For the purpose of the inner model evaluation, the variance inflation factor (VIF) values that were derived for exogenous constructions are shown in the table. If the VIF result is less than 5.00, it indicates that the degrees of collinearity among the variables are acceptable. Based on the Variance Inflation Factor (VIF) results, which were used to check for collinearity between the exogenous factors in the inner model of the research project on how people buy things for babies, it was discovered that any such levels were usually low.

In the following table 6.9, you will find information on how to evaluate collinearity among exogenous constructs in the inner model using the variance inflation factor (VIF) values available. When it comes to structural equation modeling, collinearity is an issue since it has the potential to exaggerate standard errors and lead to conclusions that are deceptive. The variance inflation factor (VIF) values are used to determine the extent to which an estimated regression coefficient's variance expands as a result of collinearity with other variables.

The coefficient of determination (VIF) values for each construct are presented in the table, which assists in determining the degree of multicollinearity. When compared to comparable constructions, the value inflation factor (VIF) for supply chain collaboration (SCC) is found to be 2.046. The fact that the VIF is relatively low indicates that the SCC does not have a large degree of collinearity with the other constructs in the model. SCMRT, which stands for Supply Chain Management Rail Transport, has VIF scores of 3.002 and 3.357, respectively. There is a correlation between the first value and its collinearity with SCC, while the second value represents its collinearity with SCP. Because both of these numbers are lower than the criterion commonly used, which is either 5 or 10, it can be concluded that SCMRT does not display problematic levels of collinearity with the other constructs. Because there are no reported VIF values in the table, it may be inferred that the collinearity of Supply Chain Performance (SCP) with other constructs is either not a problem or was not evaluated in this particular context. Top Management Commitment (TMC) exhibits VIF values of 3.002 when collinear with SCC, 1.000 when collinear with SCMRT, and 3.229 when collinear between SCP and SCMRT. The VIF of 1.000 with SCMRT indicates that this construct has no collinearity. On the other hand, the values of 3.002 and 3.229 for SCC and SCP, respectively, are still below the threshold, indicating that the degrees of collinearity are manageable. According to the VIF results shown in the table, the collinearity between the exogenous constructions is within the permissible ranges. In order to guarantee accurate estimates for the connections being investigated, none of the constructs display a significant degree of collinearity, which could potentially affect the model's findings.

Table 6.9: Evaluating Collinearity for exogeneous constructs through VIF outer model

Indicators	**VIF outer model**	**Indicators**	**VIF outer model**
SCC1	1.796	**SCP1**	2.481
SCC2	1.939	**SCP2**	3.817
SCC3	2.112	**SCP3**	4.361
SCC4	3.053	**SCP4**	3.791
SCC5	2.386	**SCP5**	3.115
SCC6	1.827	**SCP6**	3.632
SCMRT1	2.149	**TMC1**	3.772
SCMRT2	2.233	**TMC2**	3.873
SCMRT3	2.624	**TMC3**	4.590
SCMRT4	3.347	**TMC4**	4.099
SCMRT5	3.453	**TMC5**	3.575
SCMRT6	1.856	**TMC6**	4.304

6.6.2 Hypothesis formulation and testing

To evaluate the hypothesis in the structural model, bootstrapping was used in conjunction with mediator analysis. With this method, it was possible to investigate not only the direct impacts of each exogenous construct on the endogenous latent variable but also the mediation effects in cases where they were relevant. The research objective was to experimentally evaluate the theoretical components and linkages that were provided in the model. This was accomplished by isolating and evaluating these interactions. This allows for an evaluation of the overall empirical validity and robustness of the structural model. The findings give insights into how each exogenous variable affects the endogenous latent variable, both directly and indirectly via possible mediators. Through this meticulous study, we verify that the associations that have been discovered are statistically significant and provide a major contribution to our understanding of the dynamics that are present within the framework that has been investigated. Based on the study and interaction with industry experts, the following Hypotheses have been formulated:

Hypotheses for the study

H1: Top Management Commitment significantly influence Supply Chain Management Rail Transport

H2: Top Management Commitment significantly influence Supply Chain Collaboration

H3: Top Management Commitment significantly influence Supply Chain Performance

H4: Supply Chain Management Rail Transport significantly influence Supply Chain Collaboration

H5: Supply Chain Collaboration significantly influence Supply Chain Performance

H6: Supply Chain Management Rail Transport significantly influence Supply Chain Performance

Table 6.10: Results of hypotheses testing

Hypotheses	Path	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T- Value	P Values	Inference
H1	TMC -> SCMRT	0.817	0.818	0.030	27.217	0.000	Accepted
H2	TMC -> SCC	0.333	0.340	0.108	3.094	0.002	Accepted
H3	TMC -> SCP	0.401	0.410	0.128	3.127	0.002	Accepted
H4	SCMRT -> SCC	0.417	0.416	0.103	4.048	0.000	Accepted
H5	SCC -> SCP	0.235	0.228	0.092	2.550	0.011	Accepted
H6	SCMRT -> SCP	0.288	0.287	0.083	3.469	0.001	Accepted

The table 6.10 displays the results of a hypothesis test that examined the impact of various constructs within the context of supply chain management. Path coefficients, sample means, standard deviations, t-values, and p-values are the metrics that are used in the process of evaluating each candidate hypothesis.

H1: Top Management Commitment (TMC) significantly influences Supply Chain Management Rail Transport (SCMRT).

The sample mean is 0.818, and the standard deviation is 0.030. This connection's path coefficient is 0.817, and the sample distribution is 0.030. The fact that the t-value is 27.217 and the p-value is 0.000 indicates that the impact is quite significant. Therefore, Hypothesis 1 is supported, which suggests that the dedication of top management has a considerable impact on supply chain management in rail transport. This effect is both strong and statistically significant.

H2: Top Management Commitment (TMC) significantly influences Supply Chain Collaboration (SCC).

The sample mean is 0.340, and the standard deviation is 0.108. The path coefficient is 0.333, and the sample mean measures 0.340. The fact that this impact is statistically significant is shown by the fact that the t-value is 3.094 and the p-value is 0.0022. Because of this, Hypothesis 2 is accepted, indicating that the dedication of top management has a considerable impact on supply chain cooperation, albeit a modest one.

H3: Top Management Commitment (TMC) significantly influences Supply Chain Performance (SCP).

The sample mean is 0.410, and the standard deviation is 0.128. This connection's path coefficient is 0.401, and the sample mean is 0.410. It seems that there is a statistically significant influence, as shown by the t-value of 3.127 and the p-value of 0.002. Because of this, Hypothesis 3 is accepted, which demonstrates that the dedication of top management has a major impact on supply chain performance.

H4: Supply Chain Management Rail Transport (SCMRT) significantly influences Supply Chain Collaboration (SCC).

The sample mean is 0.416, and the standard deviation is 0.103. The path coefficient is 0.417, and the sample mean measures 0.416. It may be concluded that this impact is statistically significant, as shown by the t-value of 4.048 and the p-value of 0.000. Therefore, Hypothesis 4 is accepted, which indicates that rail transit in supply chain management has a substantial influence on the cooperation that occurs inside supply chain management.

H5: Supply Chain Collaboration (SCC) significantly influences Supply Chain Performance (SCP).

Taking into account the sample mean of 0.228 and the standard deviation of 0.092, the route coefficient in this instance is 0.235. It may be concluded that there is a statistically significant impact based on the t-value of 2.550 and the p-value of 0.011. As a result, Hypothesis 5 is accepted, which suggests that cooperation within the supply chain has a positive impact on its performance.

H6: Supply Chain Management Rail Transport (SCMRT) significantly influences Supply Chain Performance (SCP).

The sample mean is 0.287, and the standard deviation is 0.083. The path coefficient is 0.288, and the sample mean is sampled. The statistical significance of this impact is demonstrated by the t-value of 3.469 and the p-value of 0.001. This demonstrates that supply chain management rail transport has a major impact on supply chain performance, which was shown figure 6.2 by the acceptance of hypothesis H6.

The evidence lends credence to each and every hypothesis. A major influence is made by the dedication of top management on both the management of the supply chain rail transport and cooperation, which in turn have an effect on the performance of the supply chain. This suggests that there is a consistent impact route in which strategic leadership and certain management techniques are essential for improving performance outcomes in the supply chain.

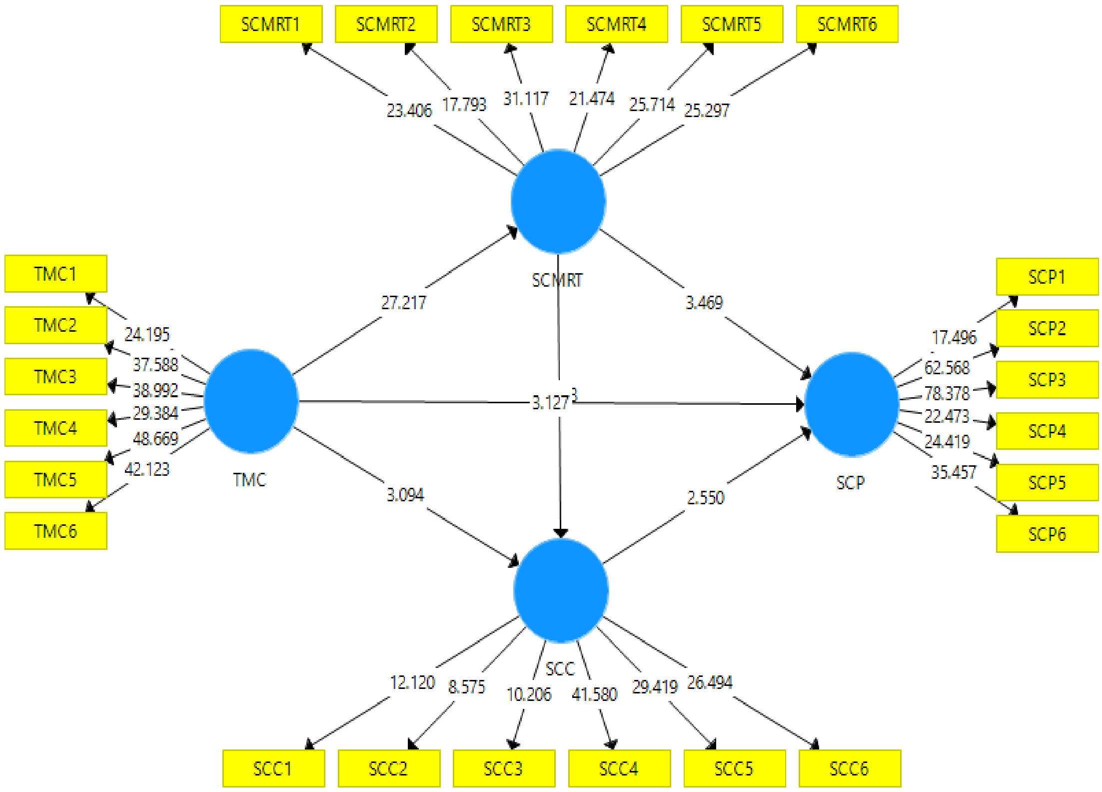

Figure 6.2: SEM for the study

Source: Field Survey Data

6.7 Effect size F- square (f^2)

All of the exogenous latent variables in structural modeling have the potential to have a considerable effect on a number of other variables included within the model. Estimating the magnitude of the effect requires knowing the extent to which the absence of an exogenous latent variable has an influence on the dependent variable. To do this, a comparison is made between the change in R^2 whenever the variable is included in the model and when it is omitted from the model. A significant shift in the coefficient of determination (R^2) suggests a bigger impact size, which shows that the latent variable has made a stronger contribution to the model. In addition to R^2 values, p-values, t-values, and bootstrap findings, the effect size is an extremely important factor to think about. In accordance with Cohen's (1988) classification system, effect sizes may be classified as follows: small (f^2 = 0.02), medium (f^2 = 0.15), and big (f^2 = 0.35). The formula that is used to determine the f2 effect magnitude in this investigation is as follows:

$$f^2 = \frac{R^2 \text{ included} - R^2 \text{ excluded}}{1 - R^2 \text{ included}}$$

This calculation provides insight into the magnitude of the latent variable's impact on the model, aiding in the interpretation of its significance and contribution.

Table 6.11: Effect Size F-square

Constructs	SCC	SCMRT	SCP	TMC
Supply Chain Collaboration (SCC)			0.093	
Supply Chain Management Rail Transport (SCMRT)	0.118		0.085	
Supply Chain Performance (SCP)				
Top Management Commitment (TMC)	0.076	**2.002**	**0.171**	

This table 6.11 provides the effect size f^2 values for a number of different constructs. These values are used to determine the extent to which one construct impacts the other constructs in the model under consideration. In order to evaluate the strength of the link between the constructs, the f^2 value is used. The values indicate whether the effects are small, medium, or big, depending on the customary criteria that are available.

When it comes to forecasting Top Management Commitment (TMC), Supply Chain Collaboration (SCC) has an impact size f^2 value of 0.093. This figure, considered low, indicates that SCC has a relatively small influence on TMC. In this table, the lack of numbers for SCC's impact on other constructions may indicate that its influence is small.

When it comes to forecasting Supply Chain Performance (SCP), Supply Chain Management Rail Transport (SCMRT) shows an effect size f^2 value of 0.118, whereas when it comes to predicting TMC, it demonstrates a value of 0.085. In comparison, the value of 0.085 is deemed to have a minimal impact, while the value of 0.118 is slightly higher than the threshold for a small effect. Based on these findings, it can be concluded that SCMRT has a moderate influence on SCP but a negligible effect on TMC. The table does not include any f^2 values that are associated with Supply Chain Performance

(SCP), which is a construct that impacts other constructs. This absence may indicate that the effect sizes of SCP are either not substantial or have not been measured in this particular scenario. When it comes to predicting SCC, SCMRT, and SCP, respectively, Top Management Commitment (TMC) demonstrates impact sizes of 0.076, 2.002, and 0.171. A very strong influence of TMC on SCMRT is shown by the value of 2.002, which is much higher than the other values. This implies that TMC has a significant impact on this construct. By comparison, the impact size of 0.171 on SCP is suggestive of a medium effect, while the effect size of 0.076 on SCC is regarded to be a moderate effect.

The data shown in the table demonstrates that TMC has the most substantial influence of all the constructions, especially with regard to SCMRT. Other constructions, such as SCC and SCMRT, have impacts that are either less significant or nonexistent on the targets that they are intended to affect. This distribution of effect sizes shows the varied strengths of links among the components in the model, which gives insight into the aforementioned strengths.

6.8 Blindfolding and Stone-Geisser's Q^2

A method called "blindfolding," which is part of Partial Least Squares Structural Equation Modeling (PLS-SEM), was used in this study to figure out how useful the model was for making predictions by computing Q-square (Q^2). This method includes removing data points from the observed dataset of endogenous latent variables in an iterative manner, with the omission distance called D serving as the basis for the omission. It does this by assessing the model's capacity to anticipate data points that have been left out, which helps evaluate how effectively the model predicts outcomes.

For this particular research project, an omission distance of six was determined. This distance is within the suggested range of five to ten for the most effective blindfolding techniques (Hair et al., 2012). The number of samples that were utilized for the assessment was 145, and the fact that the division by D was not an integer indicates that the testing was conducted with adequate precision over a sufficient number of samples. It was discovered that the Q^2 values derived by blindfolding were more than zero, which is an indication that the model has a high level of predictive relevance. In accordance with the findings of Hair et al. (2012), Q^2 values that are larger than zero indicate that the model is capable of accurately predicting observed values. This demonstrates that the model is capable of generalizing and properly forecasting outcomes based on the connections and parameters that are specified in the structural equation model. Additionally, Stone-Geisser's Q^2, which is mentioned in the context of PLS-SEM, provides additional support for the assessment of predictive relevance. This is in accordance with the ideas that were outlined by Geisser (1974) and Stone (1974). An increase in trust in the applicability and reliability of the path model in capturing real-world connections among the latent variables that were investigated is brought about by the findings of this research demonstrate that the path model that was applied in the study is capable of accurately predicting the values that were observed.

For the purpose of this research, the following table presents the findings on the coefficient (R^2) and the predictive relevance (Q^2):

Table 6.12: Co-efficient (R^2) and Predictive Relevance (Q^2)

Latent Variable	**R^2**	**Q^2**
Supply Chain Collaboration (SCC)	0.511	0.282
Supply Chain Management Rail Transport (SCMRT)	0.667	0.415
Supply Chain Performance (SCP)	0.708	0.546

The following three latent variables are included in the table 6.12: supply chain collaboration (SCC), supply chain management rail transport (SCMRT), and supply chain performance (SCP). The table also includes the coefficient of determination (R^2) and the predictive relevance (Q^2) for each of these variables. These metrics assess the extent to which each construct within the model can explain phenomena and how relevant it is to making predictions. With an R^2 value of 0.511, Supply Chain Collaboration (SCC) is able to explain roughly 51.1% of the variation in SCC. This indicates that the predictors in the model are responsible for explaining the variance. A Q^2 score of 0.282 indicates that the model has a reasonable amount of predictive relevance, indicating that it is able to predict the outcomes associated with SCC to a satisfactory degree.

The R^2 value for Supply Chain Management Rail Transport (SCMRT) is 0.667, which indicates that the predictors are responsible for explaining 66.7% of the variation in SCMRT. This high value suggests that the model has a powerful capacity for explanation. The Q^2 value of 0.415 shows a strong degree of predictive relevance, which suggests that the model has a considerable potential to predict outcomes for SCMRT as it has a good level of predictive relevance. The Supply Chain Performance (SCP) variable has the greatest R^2 value, which is 0.708. This indicates that the predictors are responsible for explaining 70.8% of the variation in SCP variability. This is evidence that the SCP has a powerful capacity for explanation. These findings are further supported by the Q^2 value of 0.546, which indicates that the model has strong predictive relevance and suggests that it has a solid capacity to foresee the results of SCP projects.

Figure 6.3 demonstrate that the model has various degrees of explanatory power and predictive significance across the latent variables. Notably, the SCP variable has the highest values of both R^2 and Q^2. This demonstrates that the model is very successful at explaining and forecasting supply chain performance. Additionally, it demonstrates a decent level of efficacy in predicting supply chain management, rail transport, and supply chain collaboration.

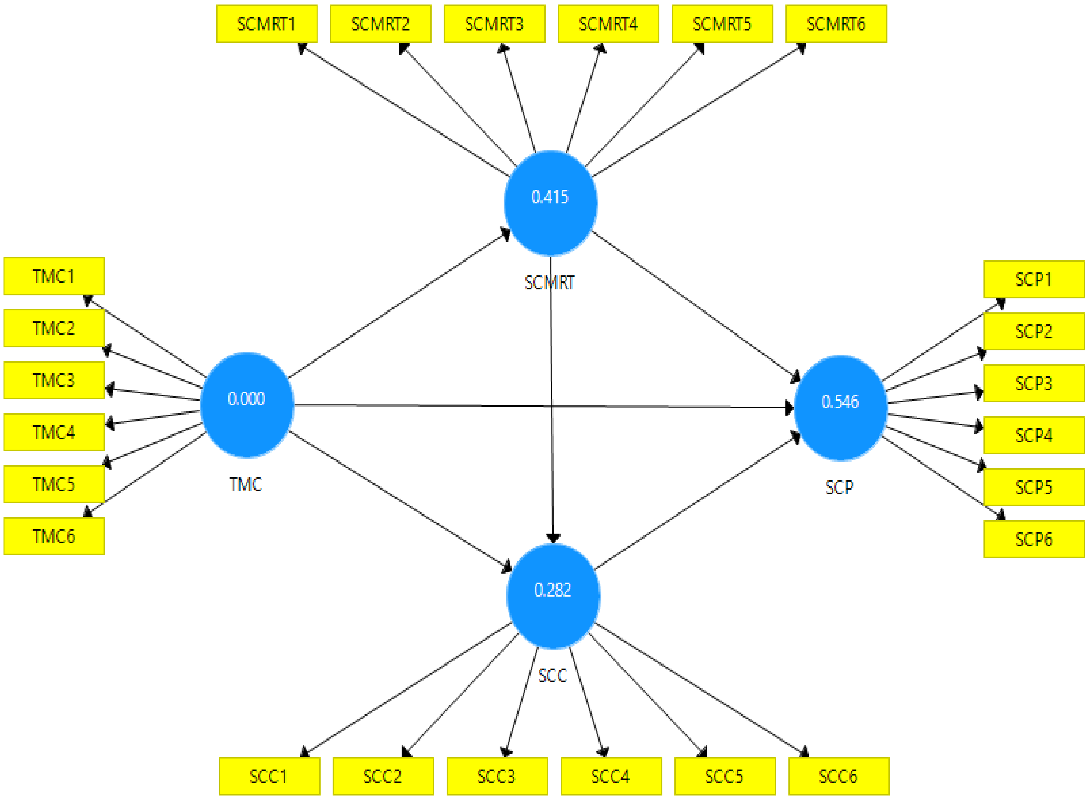

Figure 6.3: Blindfolding and Predictive Relevance of Model

Source: Field Survey Data

Calculating q^2 effect size

The Q^2 effect size is a measure of predictive significance that quantifies the influence of incorporating certain variables in the model. This effect size is generated using the Partial Least Squares Structural Equation Modeling (PLS-SEM) technique. This provides insight into the extent to which the model is able to anticipate events that are beyond what would be predicted by chance. For the calculation, the formula is:

$$q^2 = \frac{Q^2 \text{ included} - Q^2 \text{ excluded}}{1 - Q^2 \text{ included}}$$

In order to interpret the Q^2 effect magnitude, a comparison between the estimated value and the defined criteria must be made. Good predictive relevance is shown by Q^2 values that are more than zero, as stated by Hair et al. (2012). This indicates that the model is able to accurately anticipate the data points that have been seen. The effect sizes of Q^2 provide additional granularity to the analysis.

A value between 0.150 and 0.349 indicates a medium effect size, implying that there is a perceptible influence and moderate predictive relevance. • A Q^2 effect size of 0.350 or greater indicates a large effect, indicating that the included variable has considerable predictive relevance and a strong impact.

When the Q^2 effect sizes are less than 0.150, the included variable has a minimal predictive relevance and a lower influence on the model's capacity to predict outcomes. This is because the Q^2 effect sizes are regarded as "small."

The Q^2 effect size allows researchers to measure and analyze the relative influence of predictive relevance in PLS-SEM. This allows them to assess the model's importance and its robustness in terms of predicting observed data points.

In Partial Least Squares Structural Equation Modeling (PLS-SEM), the Q^2 effect size is used to figure out how important each latent component is for making predictions. The incorporation of each component reveals the degree to which the model is able to accurately forecast the values that have been seen. Higher Q^2 values indicate that the constructs contribute significantly to the model's capacity to explain and forecast the dependent variables, indicating that they have greater predictive significance.

Table 6.13: Q^2 Effect Size

Constructs	Supply Chain Performance (SCP)
Supply Chain Collaboration(SCC)	0.428
Supply Chain Management Rail Transport (SCMRT)	0.495
Supply Chain Performance (SCP)	0.702
Top Management Commitment(TMC)	0.731

The table 6.13 shows the Q^2 effect size values for the various constructions included in the model. It shows how much each construct helps to explain the variation in the endogenous components. The Q^2 effect size is found by looking at how well the model can predict things.

It has been determined that the Q^2 impact size for supply chain collaboration (SCC) is 0.428. This result indicates that the Supply Chain Performance (SCP) construct explains a considerable percentage of the variation, indicating that it has a moderate degree of predictive significance for the Supply Chain Control (SCC) construct.

It has been determined that the Q^2 impact size for Supply Chain Management Rail Transport (SCMRT) is 0.495. The fact that this value is greater than SCC demonstrates that it has a more relevant predictive power. SCMRT contributes a significant amount to the variance in SCP, indicating the importance of its role in the model's ability to explain phenomena. When it comes to Supply Chain Performance (SCP), the Q2 impact size is measured at 0.702. SCP has a strong predictive relevance inside the model, which means that it explains a significant percentage of the variation in the constructs that it impacts. This high score highlights the fact that SCP has great predictive relevance.

With a Q^2 impact size of 0.731, Top Management Commitment (TMC) has the greatest total effect size. This number shows that there is a very high predictive relevance, which suggests that TMC has a significant influence on explaining the variation in SCP and, as a result, plays an important part in the entire model.

However, TMC has the biggest impact size, despite the fact that all components have strong predictive significance. The Q^2 values underline the significance of each construct in terms of its ability to explain the variation in the model, hence highlighting the contributions that each construct makes to the overall explanatory power of the research.

6.9 Importance-Performance Matrix Analysis:

We can use the significance-performance matrix analysis (IPMA) to figure out how important different exogenous constructs are in a structural model and how well they work, especially when looking at how they affect an endogenous construct. In this study, two important metrics are combined: total impacts and index values. These metrics, which determine importance and performance, respectively, are combined.

The term "importance" in IPMA refers to the total influence that each exogenous construct has on the endogenous variable included in the route model. It is possible to means the total effects show how much each exogenous construct contributes to the formation of the target variable. They can be used to measure the direct and indirect effects that each exogenous construct has on the endogenous construct. Larger overall effect are considered more significant because they have a stronger impact on the endogenous construct that is ultimately produced. On the other hand, performance is a measurement that determines how well each exogenous construct performs in relation to the scores of its latent variables. This measure reflects the real ability of each building to exhibit its intended impact inside the model, so it may be accurate. Higher performance scores indicate that the construct is more successful in performing the function that it was designed to accomplish within the structural framework. The Interpersonal Performance Measurement Analysis (IPMA) gives a visual picture in Figure 6.4, how each external construct strikes a balance between relevance and performance by comparing the overall impacts (importance) to the performance ratings. In the upper-right quadrant of the matrix, the constructs that are positioned display high significance (strong total effects) in addition to high performance, indicating that they are both influential and effective. In contrast, constructs in the lower left quadrant may have smaller overall effects and worse performance. This means that they make a smaller contribution to the endogenous construct and may need to be improved upon or studied further (Martilla & James, 1977; Slack, 1994). Analyzing the performance matrix (IPMA) for the model depicted in the picture is crucial.

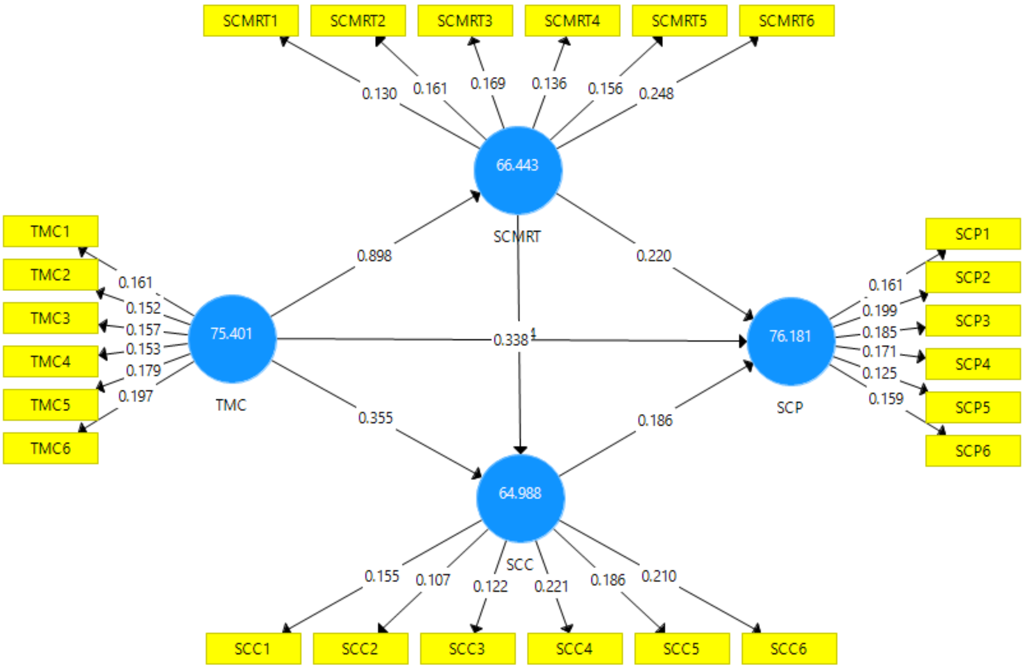

Figure 6.4: IPMA map for exogeneous and endogenous latent variables

Source: Field Survey Data

6.9.1 Importance-Performance matrix analysis (Construct wise):

The Importance-Performance Matrix Analysis (IPMA) in Figure 6.5 provides a complete perspective of the relative influence and operational efficacy of exogenous constructs on the endogenous construct is provided by the Importance-Performance Matrix Analysis (IPMA), which is an acronym for it. The expression "importance" is located along the X-axis, and it depicts the overall impact that each component has inside the structural model. Compared to other constructs in the model, those with larger total effects are positioned farther to the right on the X-axis. This indicates that these constructions have more power or significance in influencing.

On the Y-axis, performance represents the mean or average of each construct. This number reflects how effective or successful each construct is in performing its intended purpose within the model. In the study conducted by Hair et al. (2021), Rigdon et al. (2011), Hock et al. (2010), Volckner et al. (2010), and Schloderer et al. (2014), the constructs that have higher mean values are plotted higher on the Y-axis. This indicates that these constructs perform better in manifesting their latent variable scores and contributing positively.

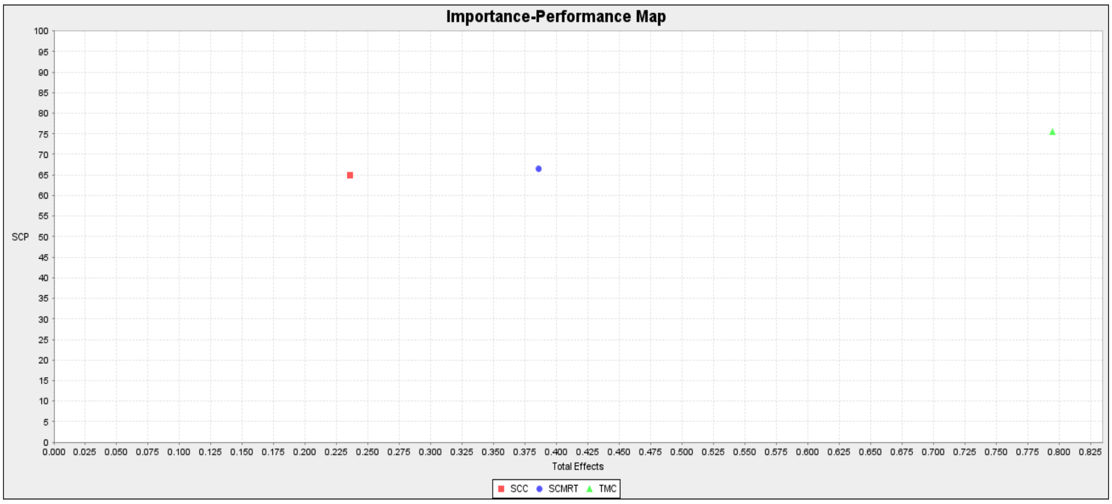

Figure 6.5: Importance -Performance Matrix Analysis constructs wise

Source: Field Survey Data

Table 6.14: IPMA construct- wise Analysis

Latent Constructs	Importance (Total Effects)	Performances (Index values)	Value
Supply Chain Collaboration (SCC)	0.235	64.988	76.42
Supply Chain Management Rail Transport (SCMRT)	0.386	66.443	76.57
Top Management Commitment (TMC)	0.795	75.401	76.98

The table 6.14, known as the Importance-Performance Matrix Analysis (IPMA), provides a comprehensive evaluation of a number of different latent constructs in terms of their overall impacts (importance) and their performance (index values) with respect to the endogenous construct. An IPMA study combines the significance of latent variables with their performance in order to provide direction for strategic decision-making, especially with regard to the enhancement of marketing activities.

This study is based on Importance-Performance Map Analysis (IPMA), which examines both the significance of each construct in the model as well as its performance. This evaluation allows for a better understanding of which constructs contribute the most to the model and how well they are functioning in relation to their significance.

The important value of Supply Chain Collaboration (SCC) is 0.235, which indicates that it significantly contributes to the model in terms of its overall impact or contribution. The performance index's values are 64.988 and 76.416, respectively. The fact that the relevance score for SCC is comparatively lower than the scores for other constructs implies that while it is a feature in the model, its influence is not as significant as it might be. With a value of 64.988 indicating its current performance and a goal value of 76.416 suggesting the ideal performance level, the performance index values show that SCC performs pretty well. The target value is a representation of the desired level of performance.

When compared to SCC, Supply Chain Management Rail Transport (SCMRT) shows a higher significance value of 0.386, which indicates that it makes a more significant contribution to the model by comparison. 66.443 And 76.567 are the values assigned to the SCMRT performance index. This demonstrates that SCMRT not only has a significant influence but also functions relatively well, despite the fact that there is still potential for development in order to achieve the level of performance that may be considered ideal.

Not only does Top Management Commitment (TMC) have the highest significance value, which is 0.795, but it also highlights the crucial position that it plays in the model. The values of its performance index are 75.401 and 76.976, respectively. The high relevance score indicates that TMC is a significant driver in the model, and the fact that its performance is reasonably near to the goal value indicates that it is functioning well and is almost reaching the level of performance that is wanted.

The construct-wise examination of the IPMA in figure 6.6 reveals that the Top Management Commitment (TMC) construct is the most important one in the model, and it is performing very close to the level that was intended. The Supply Chain Management Rail Transport (SCMRT) also plays a large role and is operating reasonably well. On the other hand, the Supply Chain Collaboration (SCC) has a lesser effect and performance, which suggests that it may need further attention or improvement.

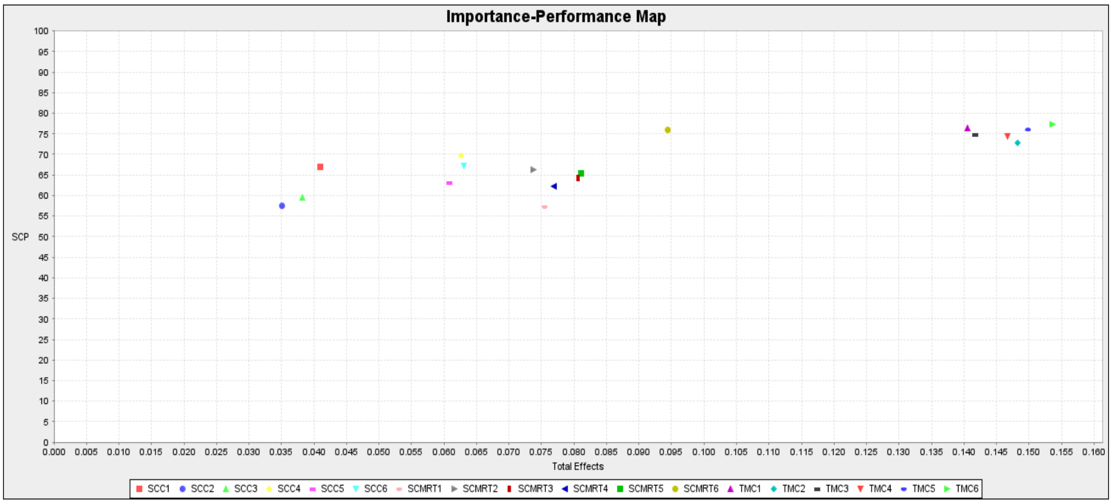

Figure 6.6: Importance -Performance Matrix Analysis indicator wise

Source: Field Survey Data

6.9.2 Importance-Performance matrix analysis (Indicators wise):

The Important – Performance Matrix Analysis (IPMA) indicates the relative importance and performance of exogenous latent variable indicators in their association with endogenous construct.

Table 6.15: IPMA Indicator Analysis

Indicators	Performances (Index values)	Importance (Total Effects)	Value
SCC1	67.069	0.029	65.017
SCC2	57.414	0.020	65.008
SCC3	59.483	0.023	65.011
SCC4	69.655	0.041	65.029
SCC5	63.103	0.035	65.023
SCC6	67.241	0.039	65.027
SCMRT1	57.241	0.038	66.481
SCMRT2	66.207	0.048	66.491
SCMRT3	64.310	0.050	66.493
SCMRT4	62.241	0.040	66.483
SCMRT5	65.345	0.046	66.489
SCMRT6	75.862	0.073	66.516

Indicators	Performances (Index values)	Importance (Total Effects)	Value
TMC1	76.379	0.108	75.509
TMC2	72.759	0.102	75.503
TMC3	74.828	0.105	75.506
TMC4	74.483	0.103	75.504
TMC5	76.034	0.120	75.521
TMC6	77.241	0.132	65.017

In table 6.15, an analysis of indicators is shown. This study is based on importance-performance map analysis (IPMA), which evaluates the significance of different indicators in addition to their performance characteristics.

The following are indicators of Supply Chain Collaboration (SCC). The performance scores of SCC1 through SCC6 range from 57.414 (SCC2) to 69.655 (SCC4). These results are very varied. The SCC4 indication has the greatest performance index, which is 69.655, indicating that it is the most successful indicator in its area among the SCC indicators. In terms of significance, the overall effects of SCC1 through SCC6 range from 0.020 (SCC2) to 0.041 (SCC4) depending on the specific case. Simultaneously, SCC4 exhibits the highest significant effect of 0.041, suggesting that it is the indicator with the greatest influence on SCC. The Value column for SCC indicators maintains a steady value of around 65, with SCC4 displaying a slight peak at 65.029. This indicates that it can properly balance high performance and high significance.

As far as the Supply Chain Management Rail Transport (SCMRT) indicators are concerned, the performance ratings for SCMRT1 through SCMRT6 range from 57.241 (SCMRT1) to 75.862 (SCMRT6). The performance index for SCMRT6 is the maximum possible, coming in at 75.862, which indicates that it performs the best in its category. When it comes to significance, the indications range from 0.038 (SCMRT1) to 0.073 (SCMRT6), respectively. The fact that SCMRT6 has the greatest overall effect of 0.073 demonstrates that it is the indication that has the most significant impact on SCMRT. The Value column reveals that SCMRT6 is the highest out of all the options, with a value of 66.516, highlighting both its better performance and its significance.

Top Management Commitment (TMC) Indicators: The performance ratings for TMC1 through TMC6 range from 72.759 (TMC2) to 77.241 (TMC6). The best TMC indicator is TMC6, with a performance index of 77.241. TMC1 through TMC6 have total impacts that range from 0.102 (TMC2) to 0.132 (TMC6). This is where the relevance of these effects lies. TMC6 has the highest overall effect of 0.132, indicating that it has the greatest impact on TMC. The value column indicates that TMC6 also has the highest value, which is 65.017. Additionally, this value is much lower than the values of other TMC indicators, which suggests that there is a disparity between its performance and relevance and its total value evaluation.

The table shows that TMC6, SCMRT6, and SCC4 have the highest level of performance and the most significant impact within their respective constructions. Although these indicators exhibit great performance and relevance, their values indicate that they have a variable influence on overall outcomes. Despite its high performance and importance, TMC6 has seen a significant decrease in value.

6.10 Conclusions

This chapter highlights the importance of several factors affecting the performance of the supply chain in Indian railway transport. The findings highlight the need for improved coordination and technological advancements to achieve more efficient and robust supply chains. By identifying these key drivers Indian Railways can employ strategies to improve service delivery and operational efficiency. The next chapter outlines the findings of the study based on analysis and identifies opportunities for further improvement and innovation in the sector.

CHAPTER 7

CONCLUSIONS AND FUTURE SCOPE

7.1 Findings of the Study

The study focussed on supply chain in Indian rail transport and identified the issues and barriers and further employed certain indicators to assess several constructs, including Top Management Commitments (TMC), Supply Chain Collaborations (SCC), Supply Chain Management Rail Transports (SCMRT), and Supply Chain Performances (SCP).

The finding of the study are:

1. An improvement the Indian railway transport system needs improvement in the parameters of Indian railway transport supply chain management system. These parameters are availability, quality of railway services and reliability.
2. Barriers which needs to manage for effective Indian railway transport system are lack of policy support for strategic, lack of IT skilled or trend manpower, an efficient information technology system or insufficient support from downstream partners and lack of responsiveness.
3. For establishing long term relationship with supplier's Top management is crucial.
4. Information sharing among trading partners place in important role in forging strong trading partner's relationship.
5. The supply chain performance of Indian rail transport depends on the management of barriers within the Indian railway transport supply chain management system.

7.2 Contribution of the Study

Based on the findings of this study, the contributions can be categorized into three main sectors: Indian Railways, suppliers, community, or stakeholders.

1. Indian Railways

a) ***Optimizing Supply Chain Operations:*** The study provides valuable insights on how Indian Railways can optimize its supply chain through better operations, reducing operating costs and driving productivity effectiveness.

b) ***Management commitment:*** This emphasizes the role of top management in fostering strong supplier relationships, integrating technologies, and ensuring continuous improvement in the supply chain tree.

c) ***Adoption of IT-enabled SCM:*** By identifying barriers such as lack of IT-skilled people and inefficient information systems, the study suggests ICT-enabled adoption by the Indian Railways IT-enabled SCM -Focus on establishing development and training programs with stakeholders.

d) ***Enhancing performance metrics:*** Research has shown that adoption of models such as TOPSIS and AHP for empirical use ensures accuracy of performance metrics, leading to better decision-making and product delivery management is effective.

e) ***Addressing barriers:*** By identifying important barriers (e.g., lack of implementation agreements, unwillingness to support), the study provides a strategy for addressing these challenges though improve the SCM process

2. Suppliers

a) ***Strengthening relationships with suppliers:*** Findings suggest increased collaboration with suppliers, enhanced long-term contracts, and strategic partnerships is needed to improve the supply chain. Suppliers can benefit from clear communication and alignment of objectives with the Indian Railways.

b) ***Vendor Performance Analysis:*** The survey uses models such as TOPSIS to help categorize and grade suppliers based on their performance, ensuring top performing suppliers are identified and rewarded, while identifying inefficient suppliers has led to improvements.

c) ***Technology adoption and training:*** Research highlights the need for suppliers to invest in IT systems, and receive training to remain competitive. This enables better integration with Indian Railways' supply chain strategies.

d) ***Incentives Alignment:*** Formulation of supplier incentives through collaboration as suggested by the study will enhance trust between suppliers and the Indian Railways and strengthen collaboration.

e) ***Long-term involvement:*** Research recommends long-term contracts and strategic partnerships with suppliers to minimize disruption and create highly robust supply chain networks.

3. Community or stakeholders

a) ***Economic impact on local communities:*** By improving the efficiency and reliability of rail transport provision, Indian Railways can contribute to economic growth in local communities, and enable movement of goods and services more reliable.

b) ***Social Responsibility:*** The study highlights the importance of addressing environmental and social concerns, such as noise pollution and land acquisition, to ensure that Indian Railways' SCM practices have a positive impact on communities the surrounding area.

c) ***Stakeholder collaboration:*** Collaboration between Indian Railways and stakeholders, including government departments and local communities, is essential to overcome supply constraints. This collaboration helps ensure that all stakeholders implement advanced SCM performance.

d) ***Sustainability:*** The study highlights that Indian Railways' supply chain should adopt sustainable practices, such as reducing carbon footprints and improving waste management, to the environment and communities have benefited.

e) ***Policy implications:*** The study highlights the importance of government support in removing SCM barriers, encourages policy makers to support initiatives that improve the efficiency of the Indian Railways supply chain and for its customers all involved have benefited.

7.3 Limitations of the Study

a) **Narrow Geographic Scope:** This research mainly examines the Indian rail transport system, perhaps limiting the applicability of the results to other nations or areas with distinct rail infrastructure, laws, and economic situations. The distinctive features of India's rail network, including its magnitude, intricacy, and significance in the national economy, may not be relevant to rail systems in other settings.

b) **Limitations of Sample Size:** The research used a sample of 110 participants for the AHP and TOPSIS analysis and 32 participants for the M-TISM and Fuzzy MICMAC analysis. While this sample size is statistically valid, a bigger sample might provide more complete insights, especially with varied viewpoints from various areas, sectors, and stakeholder groups within the rail transport industry. The limited sample size may restrict the scope of the results and their capacity to generalize the conclusions to the broader rail industry.

c) **Method of Data Collection:** The data gathering approach mostly used self-reported questionnaires and surveys from essential stakeholders, including material suppliers, managers, and administrators. This method yields useful insights from industry experts, although it may also add biases, like respondents offering socially desired responses or being swayed by personal experiences. The absence of direct observational or operational data may constrain the research, particularly in comprehending the issues faced in rail operations.

d) **Emphasis on Technology:** The research investigates the influence of new technologies, such as IoT, blockchain, and AI, on supply chain optimization, although it fails to adequately consider the rapid progression of technical developments. The results may become obsolete if new technologies arise or current technologies advance. Furthermore, the study's scope excludes a comprehensive examination of the problems and expenses related to the implementation of these sophisticated technologies, which may impact their practicality for adoption in the Indian rail industry.

e) **Modifications in Regulations and Policies:** The research examines existing regulatory frameworks and governmental policies, including freight tariffs and public-private partnerships (PPPs), although it does not include anticipated future modifications to these policies. The changing regulatory environment, particularly within the intricate framework of Indian Railways, may lead to substantial modifications in the study's results and recommendations due to potential future policy changes.

f) **Concentrate on Supply Chain Management:** The research primarily focusses on supply chain management (SCM) in the rail transport industry. Nonetheless, supply chain management is but one facet of the many operational issues encountered by Indian Railways. Other essential domains, like human resource management, infrastructure maintenance, and passenger service quality, were not examined thoroughly. These elements significantly influence the overall performance and efficiency of the rail transport system.

g) **Inadequate resolution of short-term disruptions:** The briefly addresses the COVID-19 pandemic's effect on rail freight operations but fails to thoroughly examine other short-term interruptions, such as natural catastrophes, strikes, or economic downturns, which may significantly damage the rail supply chain. The study didn't look closely enough at how these interruptions affected the supply chain's overall resilience and recovery, which made it less useful for dealing with unexpected outside factors.

h) **Complexity of multi-criteria decision-making models:** This study uses advanced multi-criteria decision models including AHP, TOPSIS, M-TISM, and Fuzzy MICMAC, which can pose challenges for auditors and decision makers unfamiliar with these standards. Although these models provide a comprehensive analytical framework, But the complexity of these models may hinder their practical use by train operators or politicians who need clearer, more intuitive decision-making tools.

i) **Absence of Longitudinal Data:** The research is cross-sectional, concentrating on data gathered at a certain moment. This constrains the capacity to monitor long-term trends and alterations in the supply chain performance of Indian Railways. A longitudinal approach may provide profound insights into the evolution of supply chain difficulties over time, especially in relation to infrastructure expenditures or regulatory modifications.

7.4 Managerial Implications

The findings of the research study will serve as a guide for managers and assist them in making decisions to improve the Indian railway transport system. The study stresses to improve the affective parameters Indian railway transport supply chain management system. The finding of the study assists managers to focus on the critical barriers like lack of policy support for strategic or long term contorting, lack of IT skilled or trend manpower in fields, an efficient ICT system and lack of responsiveness. The research will help manager to understand Top management commitment as crucial for establishing long term relationship with suppliers.

7.5 Conclusions

The present study investigated the issues related to supply chain management in the rail transportation industry, specifically concerning the Indian Railways. Important issues and pinpoint solutions for enhancing supply chain efficacy and efficiency have been addressed. The study looked at important constructs including Top Management Commitment (TMC), Supply Chain Collaboration (SCC), Supply Chain Management in Rail Transport (SCMRT), and Supply Chain Performance (SCP).

Results from the TOPSIS model revealed that certain suppliers, particularly S1, perform better than others, a finding that was confirmed through linguistic assessments and expert opinions. This emphasizes how critical it is to have a reliable and consistent process for classifying and grading providers so that decision-makers can be better informed and the supply chain's efficacy can increase. The results underscore the need for empirical validation using techniques such as AHP and TOPSIS, which guarantee the model's precision and dependability in improving Indian Railways' supply chain management. Using the fuzzy MICMAC approach, the study identified several obstacles to IT-enabled supply chain management inside Indian Railways. Notably, obstacles such as a lack of policy support, a shortage of IT professionals, and ineffective information systems were identified as critical. To overcome these obstacles and improve the overall performance of the supply chain, a mix of best practices and government action is needed.

The SMART PLS technique was used in the research to examine variables influencing supply chain efficiency. All of the constructions (TMC, SCC, SCMRT, and SCP) have high levels of internal consistency and dependability, proving their applicability in evaluating supply chain performance. In order to achieve long-term success in the rail transport supply chain, top management commitment has been identified as a critical component impacting supplier relationships, information system development, and overall operational efficiency. It has been shown that improved supply chain cooperation boosts performance, especially in areas like incentive alignment and decision synchronization. This suggests that building solid relationships within the supply chain may result in considerable enhancements to the efficacy of operations and the provision of services. The study's conclusions have a big impact on the Indian Railways and other comparable rail transportation networks throughout the world.

The study emphasizes how important it is for senior management to actively participate in supply chain management to promote teamwork and improve performance. Furthermore, improving the efficiency of the supply chain and modernizing it depend heavily on removing the obstacles that have been found, especially those related to labor and IT infrastructure. The research also emphasizes how crucial it is to use models such as AHP and TOPSIS for empirical validation to guarantee that supply chain strategies are both theoretically and practically sound. These results imply that, to get more dependable and efficient results, decision-makers had to give top priority to incorporating these models into their supply chain management procedures.

Although this study offers insightful information on supply chain management in rail transportation, there are a few areas that may benefit from further investigation. Subsequent investigations may delve into the use of the models used in this study in distinct geographic settings or within other sectors with analogous supply chain predicaments. Furthermore, longitudinal research is required to evaluate the long-term effects of the suggested tactics on supply chain efficiency. Further investigation into the precise technical developments needed to get beyond the obstacles could also be pursued in the future, especially in the area of IT-enabled supply chain management. Examining how cutting-edge technologies like blockchain, AI, and the Internet of Things (IoT) might enhance supply chains for rail transportation may provide insightful guidance for future developments.

This research has thoroughly examined the potential and difficulties of supply chain management in the rail transportation industry. The study has identified crucial areas for development and provided useful suggestions for improving supply chain efficiency by concentrating on the Indian Railways. The results highlight the need for strong assessment models, efficient cooperation, and top management commitment in building a more resilient and efficient supply chain. The study findings will be crucial in shaping future tactics and guaranteeing long-term success as the rail transport sector develops.

7.6 Scope for Future Studies

a) **Updating railway infrastructure:** A future study could focus on upgrading India's railways, including dedicated freight tracks and improved signaling systems. Research could assess how these improvements reduce delays, promote operational efficiencies and address current structural constraints in the rail network.

b) **Digitization and Automation:** Research can examine the impact of digitization and automation technologies on railways, such as the Internet of Things (IoT), blockchain, artificial intelligence (AI) These studies can examine the effectiveness of these technologies on processes, it provides real-time analytics and optimizes inventory management for more efficient supply chain management.

c) **Connecting multiple transport systems:** Future research could explore the integration of rail with other modes, such as road, air and maritime to enhance more logistics solutions by analyzing the challenges and benefits of this integration, research can identify ways to overcome challenges and improve overall logistics.

d) **Impact of government policies:** Research could examine the impact of government policies on the efficiency of rail provision, including freight charges, private equity and public-private partnerships (PPPs) The study draws attention emphasize how these policies increase private sector engagement, cost savings and the operational efficiency of the railway system

e) **Sustainability in Rail Logistics:** A forthcoming study may examine the integration of sustainable practices in rail logistics, including the use of electric locomotives and renewable energy sources. Research may examine the ecological benefits of these activities, focusing on the mitigation of carbon emissions and the promotion of sustainable transportation options. The private sector is involved in the optimisation of resources. Research may investigate the influence of private sector participation on improving capacity utilization, load optimization, and scheduling in the rail transportation system. Research may examine how private investment and partnerships might foster innovation and improve the overall operational efficiency of rail logistics.

f) **Disruptions Caused by the Pandemic and Global Trade Dynamics:** Future studies may assess the lasting impacts of the COVID-19 pandemic on rail freight operations and supply chains. Additionally, research may investigate the influence of global trade dynamics and changing consumer expectations on India's rail logistics, providing insights into strategies for improving resilience against future disruptions.

g) **Enhancement of Resilience and Efficiency:** Research may concentrate on devising methods to enhance the resilience and efficiency of India's rail supply system. Future research may improve service delivery, reduce operational expenses, and optimize the overall effectiveness of railway logistics by proposing specific solutions.

PUBLICATIONS

Details of Publications in SCIE Journals

1. Manoj Kumar, Vipin & Ashish Agarwal (2024). Application of AHP and TOPSIS for the evaluation of Indian Railway supply chain parameters. Indian Journal of Engineering & Materials Sciences, 31, 193-207. https://doi.org/10.56042/ijems.v31i2.2109.

2. Manoj Kumar, Vipin & Ashish Agarwal (2024). Evaluation of Indian Railway's Supply Chain Parameters for Improved Sustainability under Industry 4.0 Transformation: An application of AHP and TOPSIS. Engineering Management Journal, https://doi.org/10.1080/10429247.2024.2375166.

Details of Publications in International Conferences:

1. Manoj Kumar, Vipin & Ashish Agarwal (2023). A compherehive study on supply chain management using Artificial Intelligence: An Indian Railway Perspective. Recent Advances in Intelligent Manufacturing, Lecture Notes in Mechanical Engineering, Springer. https://doi.org/10.1007/978-981-99-1308-4_8.

2. Manoj Kumar, Vipin & Ashish Agarwal (2023). A Quantification of Supply chain Management factors using Artificial Intelligence, Recent Advances in Intelligent Manufacturing, Lecture Notes in Mechanical Engineering, Springer. https://doi.org/10.1007/978-981-99-1308-4_9.

3. Manoj Kumar, Vipin & Ashish Agarwal (2024). Supply chain Management and its Role in Rail Transport. E3S Web of Conferences **556**, 01050 (2024). https://doi.org/10.1051/e3sconf/202455601050.

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APPENDIX-1

QUESTIONNAIRE ON THE SUPPLY CHAIN OF THE RAIL TRANSPORT SYSTEM

1. Name of Industry: …………………………………………………………………………

2. Address: ……………………………………………………………………………...

3. Your company is part of: (a) Supplier to Indian Railway [ ] (b) PSUs of Indian Railway [ ]

4. Email Address: …………………………………………………………………………..

5. Experience in Years: ……………………………………………………………………….

6. Position in the Industry: (a) CEO [ ] (b) Sr. Manager [ ] (c) Manager [ ]
(d) Member of Board [ ] (e) Administrator [ ] (f) Other (specify) [ ]

7. Supply Chain activity in your company is related to the following products:

(a) Automotive Parts [ ] (b) Electrical Parts [ ] (c) Electronics Parts [ ]

(d) Consumer goods [ ] (e) Other ………………………………………………….

8. Functional area: (a) Materials [ ] (b) Operations [ ] (c) Technical [ ]
(d) Marketing [ ] (e) Any other [ ]

9. Your association in years with the current organization:
(a) Less than 5 [ ] (b) 5-10 [ ] (c) 10-15 [ ] (d) more than 15 [ ]

10. Does your Industry have ISO 14001/50001 certification?

(a) YES [ ] (b) NO [ ]

11. Please rank the following issues influencing the Supply Chain of the Indian Rail Transport System.

(1. Highly dissatisfied 2.Dissatisfied 3. Neutral 4. Satisfied 5. Highly Satisfied)

S.No.	Please give weightage is to be assigned to issues in improving the Integration system with the Supply Chain of rail transport.	1	2	3	4	5
i)	Indian Railways integrates well with other modes of transport in the supply chain					
ii)	Railways' freight services are aligned with modern logistics and supply chain management systems.					
iii)	Information exchange between Indian Railways and supply chain stakeholders is seamless and efficient.					

S.No.	**Please give weightage is to be assigned to issues in improving the Integration system with the Supply Chain of rail transport.**	**1**	**2**	**3**	**4**	**5**
iv)	Rail freight services support end-to-end supply chain visibility.					
v)	Indian Railways contributes to reducing overall supply chain costs through efficient integration					

S.No.	**Please give weightage is to be assigned to issues in improving the Financial Behavior system with the Supply Chain of rail transport.**	**1**	**2**	**3**	**4**	**5**
i)	Indian Railways offers competitive pricing that helps reduce the overall cost of supply chain operations.					
ii)	The financial terms provided by Indian Railways are transparent and favorable for supply chain budgeting.					
iii)	Cost fluctuations in rail freight services are communicated well in advance to the supply chain partners.					
iv)	Indian Railways' freight rates provide a good balance between cost-efficiency and service quality.					
v)	Rail transport is considered a financially viable option compared to other modes of Transportation in the supply chain.					

S.No.	**Please give weightage is to be assigned to issues in improving the Management Perspective with the Supply Chain of rail transport.**	**1**	**2**	**3**	**4**	**5**
i)	Indian Railways management is proactive in addressing the needs of supply chain stakeholders.					
ii)	The railway management team consistently strives to improve freight service efficiency.					
iii)	Decision-making in Indian Railways is aligned with the needs of modern supply chain practices.					
iv)	Indian Railways management is open to collaboration and partnerships with supply chain managers					
v)	The management approach to problem-solving enhances the overall performance of the supply chain					

12. Please give weightage is given to following the Enablers to Improve Supply chain performance for Indian Railways Transport System.

(1. Highly dissatisfied 2.Dissatisfied 3. Neutral 4. Satisfied 5. Highly Satisfied)

S.No.	**Please give weightage to the Enabler of Availability which Improves Supply chain performance for Rail Transport System.**	**1**	**2**	**3**	**4**	**5**
i)	The availability of rail transport for cargo is consistent throughout the year.					
ii)	Railways provide flexible scheduling options for freight transportation.					
iii)	There are sufficient railway routes to support supply chain requirements across regions.					
iv)	The capacity of Indian Railways meets the needs of the supply chain during peak seasons.					
v)	Rail freight services are accessible in all key industrial areas.					

S.No.	**Please give weightage to the Enabler of Quality of Railway Service which Improves Supply chain performance for Rail Transport System.**	**1**	**2**	**3**	**4**	**5**
i)	Indian Railways ensures the safe transportation of goods without damage.					
ii)	The transit time for railway freight is competitive compared to other modes of transport.					
iii)	Railway stations and cargo terminals are equipped with modern technology to handle goods efficiently.					
iv)	Indian Railways staff are responsive and professional in handling supply chain queries and issues.					
v)	Railways provide transparent tracking systems for real-time cargo monitoring.					

S.No.	**Please give weightage to the Enabler of Reliability Service which Improves Supply chain performance for Rail Transport System.**	**1**	**2**	**3**	**4**	**5**
i)	Freight trains operate according to the scheduled timetable.					
ii)	Delays in rail freight transport are communicated promptly and efficiently					

S.No.	**Please give weightage to the Enabler of Reliability Service which Improves Supply chain performance for Rail Transport System.**	**1**	**2**	**3**	**4**	**5**
iii)	Railways maintain a consistent level of service, even during adverse weather conditions.					
iv)	Indian Railways provides reliable services for supply chain activities in urban and rural areas.					
v)	The railway system is dependable for just-in-time (JIT) deliveries.					

13. Please rank the following barriers influencing the Supply Chain of the Indian Rail Transport System.

(1. Highly dissatisfied 2.Dissatisfied 3. Neutral 4. Satisfied 5. Highly Satisfied)

S.No	**Barriers**	**1**	**2**	**3**	**4**	**5**
i)	Lack of top management Commitment					
ii)	Inefficient information and technology system					
iii)	The disinclination of the support from distributors, retailers, and dealers					
iv)	Lack of policy support for strategic/long-term contracting					
v)	Lack of IT skilled / trained manpower in field units					
vi)	Lack of collaboration among supply chain partners					
vii)	Environmental Issues					
viii)	**Natural Disasters and Weather Conditions**					
ix)	**Security concerns**					
x)	**Lack of responsiveness**					

14. Please rate the level of influence of following on top management commitment concerning the supply chain in rail transportation.

    (1-very Low………to…………….5-very High)

Item	**Item Name**	**1**	**2**	**3**	**4**	**5**
TMC1	Developing strong, long-term, collaborative relationships with suppliers					
TMC2	Using intermediaries to develop fresh suppliers and logistics infrastructure.					
TMC3	Freely exchanging information with suppliers and customers.					
TMC4	Having a clear customer and shareholder focus					

Item	Item Name	1	2	3	4	5
TMC5	Supporting the acquisition and implementation of appropriate information systems					
TMC6	Benchmarking and continual improvement					

15. Please rate the level of agreement on the following factors that influence supply chain collaboration practices in Indian rail transportation.

    (1-very Low………to…………….5-very High)

Item	Item Name	1	2	3	4	5
SCC1	Improve information sharing.					
SCC2	Decision synchronization					
SCC3	Improve incentive alignment					
SCC4	Improves the supply chain configuration.					
SCC5	Improve the enabling technology.					
SCC6	Enhanced level of collaboration					

16. Please rate the level of implementation of the following for effective supply chain management in Indian rail transport.

    (1-Very Low.........to............5-Very High)

Item	Item Name	1	2	3	4	5
SCMRT1	Designs of specialized engineering related to the upgrading locomotive power supply systems					
SCMRT2	Enhance optimal systems at a reasonable cost and receive the highest profit.					
SCMRT3	Optimization to achieve maximum energy and minimum consumption.					
SCMRT4	Introduction of mathematical algorithms for planning and scheduling					
SCMRT5	Improvement of specialized approaches to the safety assessment of railway systems in a dynamic framework.					
SCMRT6	Development of a specialized method for analyzing the performance errors of operators in digital rail control rooms.					

17. Please rate the level of the following measures in improving Supply chain performance if Indian Rail Transport.

(1-Very Low....................to................5-Very High)

Item	**Item Name**	**1**	**2**	**3**	**4**	**5**
SCP1	Improve service effectiveness for suppliers.					
SCP2	Improve operational efficiency.					
SCP3	Improve service effectiveness for the consignee.					
SCP4	Improve supplier performance.					
SCP5	Reduce Supply chain responsiveness					
SCP6	Reduce responsiveness to customers					