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MANAGERIAL BARRIERS TO SUSTAINABLE SUPPLY CHAIN MANAGEMENT: A DESCRIPTIVE STUDY IN THE MANUFACTURING INDUSTRY IN SOUTH INDIA

MASTER'S DEGREE FINAL PROJECT

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Abstract

Sustainable Supply Chain Management (SSCM) plays a vital role in promoting environmental, economic, and social sustainability across industries. However, there are several barriers to SSCM implementation, and these barriers vary from country to country and industry to industry. Studies on barriers to SSCM implementation are limited in developing countries, particularly in manufacturing industries. This study examines the current status of SSCM practices and 31 key barriers under the four internal barrier categories in two manufacturing industries, TAFE and RML, at Chennai, South India. Data was collected from the faculty working in the SCM department through a structured questionnaire and analyzed using the Best-Worst Method (BWM), a structured multi-criteria decision-making tool. The study highlights the significance of the five SSCM practices that include choosing suppliers mostly on the basis of quality standards, working closely with suppliers to address problems, regularly gathering customer input, aiming to meet future customer expectations, and putting pressure on suppliers to deliver more quickly. The results by BWM analysis indicate that Organizational barriers are the most significant barrier category compared to the other three barrier categories, Cultural, Communication, and psychological. It also indicates that nine of the top ten key barriers are from the Organizational barriers category. The findings from this study offer practical value to managers in the manufacturing industries in South India seeking to enhance SSCM outcomes, emphasizing the importance of addressing internal organizational barriers before tackling external ones. These insights lay the groundwork for future academic research and strategic industrial development.

Keywords: supply chain, sustainable supply chain management (SSCM), internal barriers, multi-criteria decision-making method (MCDM), best-worst method (BWM).

1. Introduction

Several manufacturing industries from Western countries have established their production facilities in developing nations. However, manufacturing industries face intense competition, and these industries must focus on various industrial activities to enhance production capacity. Globalization and rapid industrial growth have adversely affected both environmental and social aspects worldwide, raising a great concern for legislators and policymakers (Gadenne et al., 2009).

Sustainability is defined as a strategy that facilitates rational resource utilization for the present and allows future generations to satisfy their needs (Fritz, 2022). Supply Chain Management (SSCM) regulates all three components of environmental, social, and economic concerns, aiming to achieve improvement in all these sectors. The factors that influence the transition from SCM to SSCM include rapid production processes through cutting-edge technologies, controlled pollution levels, and restricted use of natural resources (Jalali et al., 2022).

Overall, industries in the developed nations have effectively implemented SSCM over the past twenty years. Recently, several industries in developing countries also initiated the process of SSCM implementation. However, there are several barriers that hamper SSCM implementation in developing countries, including political, organizational, cultural, and economic barriers (Jalali et al., 2022). Therefore, studies focusing on different barrier categories by country and industry perspective are needed in developing countries.

The stages of SSCM barrier detection include barrier identification, customization according to the industry, and ranking of the barriers to identify the degree of importance. There are several methods for ranking SSCM barriers; however, multi-criteria decision analysis (MCDA) is the most popular method in SSCM research.

Though there are several studies on SSCM barrier identification, only a limited number of studies have been published from the developing countries by scholars. Several investigators have identified that SSCM implementation is at a low level in developing countries, and in the emerging economy, it continues to be a major problem (Galal & Abdul Moneim, 2016). Barriers to SSCM implementation differ across various industries, making it essential to identify these obstacles within each sector. This facilitates designing strategies specific to the industries. (Narayanan et al., 2019).

In recent years, India has been progressing as a global industrial hub. Manufacturing industries contribute to the economic growth of the country, and the key industries include the automobile sector, pharmaceutical and chemical industries, and the electronics industry. Before the COVID-19 pandemic, the manufacturing sector accounted for approximately 17%

of the country's GDP. After a brief disruption between 2021-2022, Indian manufacturing industries grew steadily, and the technology-driven manufacturing industries are expected to enhance productivity. The Government of India actively supports Industry 4.0 progress in the manufacturing sector through the National Manufacturing Policy. This initiative aims to elevate the Indian manufacturing industries to global standards and increase the GDP to the level of 25% by 2025. India has developed the required transport and digital infrastructures to attract huge investments from global companies (Sharma & Sharma, 2024).

Tamil Nadu is situated on the southern end of India and has a 1076-kilometer length of coastline and seven international airports. The industrial sector of Tamil Nadu is diverse, encompassing plastics to aerospace manufacturing industries. There are about 25000 (0.25 million) factories that account for 15,6% of the total factories in India. It is progressing towards achieving a sixfold increase in the per capita income. Chennai, the capital of Tamil Nadu, is a major economic hub, and several global corporates, such as BWW, Ford, Nissan, Hyundai, and Royal Enfield, have established their manufacturing facilities here. To cater to these industries, several automotive components manufacturing industries have established their unit in Chennai (Mehta & Rajan, 2017).

Many of the major manufacturing industries have achieved international standards in manufacturing and successfully implemented SSCM in their organizations. Some industries have initiated SSCM implementation more than ten years ago and are looking forward to progress rapidly (Murugesan et al., 2012). Considering industry volume and economic contributions, we have identified two major industries from the automotive sector, Tractor And Farm Equipment (TAFE) and Rane Madras Limited (RML), to carry out the present study. The study focuses on the status of the SSCM and the barriers, in particular, the internal barrier category and key barriers that hinder SSCM implementation.

This thesis is organized as follows: Section one, Introduction, gives an overview of the SSCM and the background to understand the topic. Section two reviews the literature that provides the current scenario in SSCM research, the gaps between developed and developing countries, justification for this study, and the analysis methods. It also presents the details of the two manufacturing industries selected for the study. We also identified three research questions clearly defined in this section. Section three presents the detailed methodology adopted in this study to address these three research questions. Section four provides the detailed results based on the analysis. Section five briefs the conclusions, limitations of the study, and a note for future research.

2. Literature Review and Companies Overview

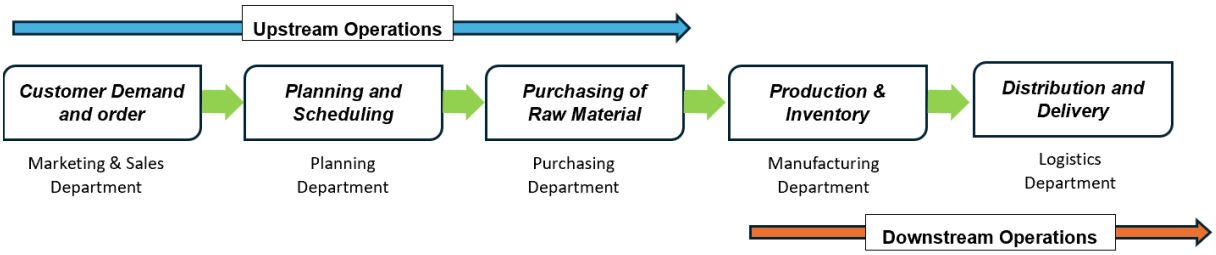
2.1. Supply Chain of a Company

The supply chain is an essential entity in every manufacturing industry that includes a sequence of events from the sourcing of raw materials to the delivery of end products to customers. The supply chain often starts and ends with the customer – a customer's decision to purchase a product triggers a chain of activities - procurement, inventory, manufacturing, and delivery, and the chain concludes when that product is delivered to the customer's hands (Van der Vorst, 2004). To effectively coordinate and control these interconnected activities, companies rely on supply chain management. The primary objective of supply chain management is to optimize the performance of each activity to add as much value as possible for the best cost-effective end product.

The supply chain management process comprises five stages essential to creating and delivering quality products and services on time and within established budgets, namely Customer Demand and Order, Planning and Scheduling, Purchasing of Materials, Inventory and Production, Distribution and Delivery (Ozturk, 2020). These stages can be grouped into upstream operations and downstream operations. Upstream operations include planning, purchasing, and manufacturing, while downstream operations involve customer orders and product delivery. Figure 1 represents the five stages of the supply chain management process generally adopted in manufacturing industries.

Figure 1:

Five stages of Supply Chain Management (Source: Own Work)



In stage 1, the customer places an order for a product, which notifies the company of what to produce and deliver. The customer service department records this order, including details such as quantity and delivery date. In stage 2, the planning department collects demand information and creates a plan for the quantity of raw materials needed, the number of products to produce, the timeline for production, and the delivery time to meet customers' demands. In stage 3, the purchasing or procurement department selects suitable suppliers, places purchase orders, inspects the raw material for quality and quantity, and manages storage and inventory

for production. In stage 4, the manufacturing department verifies the inventory, utilizes the raw material efficiently for the production of the end products, and transfers the end products to the warehouse for timely shipment. The final stage involves the logistics department ensuring the timely delivery of the end products from the warehouses to the customers through the dealer network. By completing the timely delivery of the end products to the customers, the company fulfils the supply chain cycle (Ozturk, 2020).

2.2. Sustainable Supply Chain Management (SSCM)

As industries have become increasingly global and complex, the expectations of government, stakeholders, and consumers have expanded beyond efficiency to include sustainability across all supply chain activities (Fritz, 2022). To meet these expectations, SSCM emerged as a modern approach to managing supply chains that extends beyond financial goals. It is a way of running a supply chain that not only focuses on generating profits but also prioritizes environmental care and fair treatment of people.

Altogether, SSCM monitors the supply chain cycle and ensures that the entire process is beneficial to the businesses, the customers, as well as to the employees, the planet, and resources for future generations (Baah, 2019). Therefore, a clear understanding of SSCM in the context of the three dimensions - economic, environmental, and social - is necessary to carry out the research studies and documentation.

1. Economic Dimension

The economic dimension of SSCM focuses on the business profits and operational aspects of the supply chain process. This includes sourcing of raw materials from reliable and indigenous sources, risk minimization, and maintaining market competitiveness over time. Seuring and Müller (2008) explain that this can be achieved through effective planning, close collaboration with partners, and the adoption of innovative ideas that create value for all parties involved, such as suppliers, manufacturers, transporters, and customers.

2. Environmental Dimension

The environmental dimension ensures minimal ecological impact of supply chain activities through Good Manufacturing Practices (GMP), reliance on non-conventional energy resources, sourcing degradable raw materials, waste reduction, and safe waste disposal. By integrating environmental practices, organizations contribute to regulatory compliance, pollution control, and long-term environmental protection (Seuring & Müller, 2008).

3. Social Dimension

The social dimension addresses the impact of supply chain operations on individuals, both within the organization (employees) and activities outside the organization (stakeholders). As explained by Morana (2014), social responsibility in the supply chain addresses both internal and external aspects. The internal aspects are related to fair treatment of employees, periodic training, a safe working environment, work-life balance, employees' rights, and respect for cultural diversity. The external aspects include sourcing raw materials from responsible suppliers and fostering positive relationships with stakeholders outside the company (Lambrechts, 2021). A socially sustainable supply chain makes sure that all actions are fair, open, and responsible to everyone involved.

The above three dimensions of supply chain management have evolved over a period of time through lean supply chain management and green supply chain management. The primary focus of the Lean supply chain is the economic dimension as it relates to production efficiency, material utilization, and cost reduction. The addition of Green supply chain practices to the Lean supply chain ensures that both economic and environmental dimensions are addressed together for better outcomes. Green supply chains are directly related to the environmental dimension, as they aim to minimize the environmental impact through actions such as reducing emissions, conserving energy, and promoting the reuse, recycling, and recovery of materials (Cvetić et al., 2021).

For the last two decades, industries have accepted that employees are also active stakeholders of the companies (Das, 2018). It is also recognized that both Lean and Green supply chain lack focus on employees' concerns and thereby, they often overlook the social dimension. This gap leads to the evolution of Sustainable Supply Chain Management (Osei et al., 2023). The addition of the social dimension to the economic and environmental aspects of the supply chain ensures that this gap is filled. SSCM, encompassing economic, environmental, and social aspects, ensures a more balanced and responsible supply chain strategy that aligns with global sustainability goals (Mugoni et al., 2024).

Altogether, SSCM fulfils the expectations of all the stakeholders of the supply chain. However, when implementing SSCM practices, industries often face several barriers. Therefore, the management needs to know what type of barrier they are dealing with and to develop an appropriate strategy to overcome it. The next sub-section outlines the major categories of barriers to SSCM implementation.

2.3. Barriers to SSCM

There are several barriers to the effective implementation of Sustainable Supply Chain Management (SSCM) practices. SSCM barriers vary from industry to industry and within the industry. The most common broad categories of the SSCM barriers are internal and external barriers (Sajjad et al., 2015), and most researchers follow this common categorization for their studies.

Considering the demands from the industry, investigators frame research questions and design studies specific to that industry sector. This approach enables them to identify the significant barrier categories relevant to SSCM implementation in that industry sector. Jalali et al. identified four barrier categories: financial, technology, policy, and human resources in their study on the implementation of SSCM in Iran's manufacturing industries (Jalali et al., 2022). This study focused on three internal barrier categories and one external barrier category.

Gonçalves et al. (2024) identified nine major types of barriers to overcoming challenges in sustainable supply chain management (SSCM) for small and medium-sized enterprises by expert consultations and brainstorming sessions. The barriers include organizational, regulatory, social, cultural, human resources, marketing and networking, information, supplier, financial, and technological categories (Gonçalves et al., 2024). This study focused on both internal and external barrier categories.

Similarly, Rakesh et al. (2021) identified five barrier categories in their research on the analysis of SSCM barriers in the Indian electronics industry, which include both internal and external barrier categories: policy, human resource, technology, infrastructure, and communication. Table 1 summarizes the barrier categories identified by different researchers in their studies on SSCM implementation across various industries.

Table 1:

Summary of SSCM Barrier Categories Identified by Different Researchers

Author(S)	Barrier Categories Identified
Jalali et al. (2022)	*Internal* - Financial, Technological, Human Resources. *External* - Policy
Gonçalves et al. (2024)	*Internal* - Organizational, Social, Cultural, Human resources, Financial, Technological *External* - Regulatory, Marketing and networking, Information, and Suppliers.
Rakesh et al. (2021)	*Internal* - Human resources, Technology, Infrastructure, Communication, Management Policy

An in-depth review of these studies highlights various barriers that can be grouped under internal and external. These studies emphasize designing studies based on industrial needs in the country context. Considering the above reports, and other related published reports given under references, this thesis included four specific internal barriers: Organizational Barrier, Cultural Barrier, Communicational Barrier, and Psychological Barrier. A brief explanation of these four internal barriers is presented below.

1. Organizational Barrier

Organizational barriers are related to the challenges to the concerned companies with reference to the organization structure, policies, and the management decision-making processes. For example, this includes issues such as poor coordination between departments, unclear roles and responsibilities, or resistance from upper management (Gonçalves et al., 2024). Such barriers can delay or disrupt the adoption of SSCM practices.

2. Cultural Barrier

Cultural barriers refer to the differences in social values, religious beliefs, community traditional practices, and working style. These cultural differences among the employees in the companies and the organizational capacity to manage these differences hinder collaboration and slow down the implementation of SSCM (Gonçalves et al., 2024).

3. Communicational Barrier

In any company, effective communication plays a crucial role in organizational management and customer interactions. It is emphasized in Industries that effective communication promotes better decision-making and problem-solving through collaboration and the sharing of ideas. However, companies must address the issues of miscommunication, information overload, and lack of transparency/isolation (Shahriar, 2024).

4. Psychological Barrier

Beliefs, emotions, values, and traditional norms vary among individuals and communities, often giving rise to psychological barriers. A study carried out by Chindasombatcharoen et al. (2024) in Bangladesh has shown that trust, effort, attitudinal, and normative barriers are the major psychological barriers for the adoption of innovation in agriculture.

2.4. Barriers in Developing Countries

All the industries in developing countries, including SMEs, face most of the external and internal barrier categories listed in Table 1 when implementing SSCM. Classification of the

barriers into two categories, as external and internal, is a conventional approach. Various authors have undertaken studies, including a set of selected barrier categories from the country and industry perspectives. These studies facilitate the industries in identifying the most significant barriers and developing strategies for overcoming these barriers.

External barriers play a crucial role in the SSCM implementation. Several studies from developing countries such as Pakistan, Bangladesh, Iran, India, and Indonesia have reported that organizations face significant external barriers when implementing SSCM practices. Lack of political support (Asif et al., 2019), existence of a low level of regulation (Huq & Stevenson, 2020), frequent changes in political leadership, and weak enforcement of regulation (Ehrgott et al., 2013) are the most significant external barriers identified by these authors in developing countries.

Moreover, a huge expenditure is involved for certification labels from third-party auditors without implementing the required SSCM practices (Thoti et al., 2024). Countries such as Bangladesh have also reported a lack of sufficient rules, audits, or penalties to ensure companies follow proper practices. Ehrgott et al. (2013) stated that in some cases, companies may prefer to pay pollution fines, as these costs are lower than the costs of clean-up or prevention. This trend of paying pollution fines is reported in countries such as China, India, Brazil, South Africa, and Indonesia, and such practices are considered a regulatory barrier.

Li et al. (2017) stated that companies do not see any financial benefits in adopting sustainable practices because neither the government nor the buyer provides subsidies or incentives to help cover the costs of training, consultancy, or certification. Supplier-related barriers are also significant barriers for SSCM implementation. Suppliers in developing countries often lack the necessary knowledge, expertise, and financial resources to adopt sustainable practices, as implementation of SSCM is a complex and challenging task (Gupta et al.,2020)

The external barriers stated above involve external agencies and different certifications. It requires long-term plans and additional funding. Similarly, research studies that involve external barriers require large samples, and these studies are time-consuming. Studies including both external and internal barriers are carried out by research scholars on a four- or five-year term or by the industries with exclusive funding for research and development.

Similar to the external barriers stated above, there are reports from developed countries on the internal barriers also. Gonçalves et al. (2024) identified multiple organizational and communicational barriers in Small and Medium-Sized enterprises in developing countries. Some of the common organizational barriers include the inability to work together across departments, inadequate planning for the implementation of SSCM practices, and resistance

to change. Researchers have also shown that many companies are slow to adopt new methods and approaches (Baig et al., 2020). This resistance to change is a significant reason why adopting sustainable supply chain management (SSCM) is challenging.

As global supply chains involve numerous countries, languages, and cultural differences that hinder mutual understanding, implementing SSCM becomes increasingly difficult. Harouache et al. (2024) observed in their research on supply chain in developing countries that language and cultural barriers can impede communication, leading to misunderstandings and misinterpretations of sustainability instructions between partners.

It is evident from the above studies that barriers play a crucial role in SSCM implementation in several industries, including manufacturing industries. However, the categories of barriers that impact the SSCM implementation vary widely between countries, within countries, and across industries. Considering the feasibility, this thesis exclusively focused on four internal barrier categories. Before identifying the internal barriers, it is important to study the current SSCM practices in TAFE and RML, as this formed the basis for our first research question. Next, we identified four internal barrier categories and 31 key barriers within these four barrier categories, and this formed the basis for the second and third research questions.

2.5. TAFE & RML: Overview and supply chain

Chennai, situated in the southern region of India, is a central industrial hub that hosts a diverse range of manufacturing sectors. Among the key companies based here are Tractors and Farm Equipment Limited (TAFE) and Rane Madras Limited (RML)—both recognized for their efforts toward sustainable supply chain practices. TAFE and RML are moving towards the sustainability of their supply chain operations and taking consistent efforts for a significant level of achievement by 2030. We provide the details of the sustainable supply chain activities currently adopted by these two manufacturing companies. Considering the access and the availability of an effective SCM team, we approached these two manufacturing companies for the present study.

2.5.1. TAFE (Tractor And Farm Equipment) supply chain

Tractors and Farm Equipment Limited (TAFE) was established in 1960 and has grown into a global leader in tractor manufacturing, with a current annual turnover of over INR 13,700 crores (approximately USD 1.46 billion). TAFE has identified suppliers for raw materials from more than 200 companies and has a customer base for its tractors in more than 80 countries, extending to Asia, Africa, Europe, America, and Russia (TAFE Sustainability report, 2024). Its

manufacturing facilities are certified under ISO 9001 and ISO 14001, reflecting a strong commitment to both quality management and environmental responsibility (Prabakar, 2023). TAFE is known for its excellence in manufacturing facilities, automation, and social commitment. An overview of the manufacturing company TAFE and its supply chain is given in Table 2.

Table 2:

TAFE (Tractor and Farm Equipment)

Company Overview	
Year Established	1960
Headquarters	Chennai, India
Industry	Tractor Manufacturing
Annual Turnover	1.46 billion USD
Global Reach	Asia, Africa, Europe, America, and Russia
Certifications	ISO 9001, ISO 14001
Source: *TAFE Corporate report 2024	
Note: ISO - International Organization for Standardization	
Supply Chain Overview	
Raw Material Sourcing	From more than 200 countries
Key SSCM Practices	Sustainable sourcing, Waste minimization, Energy saving, Employee rights, and Life cycle evaluation
Inventory Practices	Optimized storage, waste reduction
Final Products	Tractors and OEM parts
ESG Targets	Zero landfill (2030), Net water positive (2035), Zero emissions (2050)
Source: TAFE Sustainability Report 2024	
Note: ESG – Environmental, Social, and Governance	

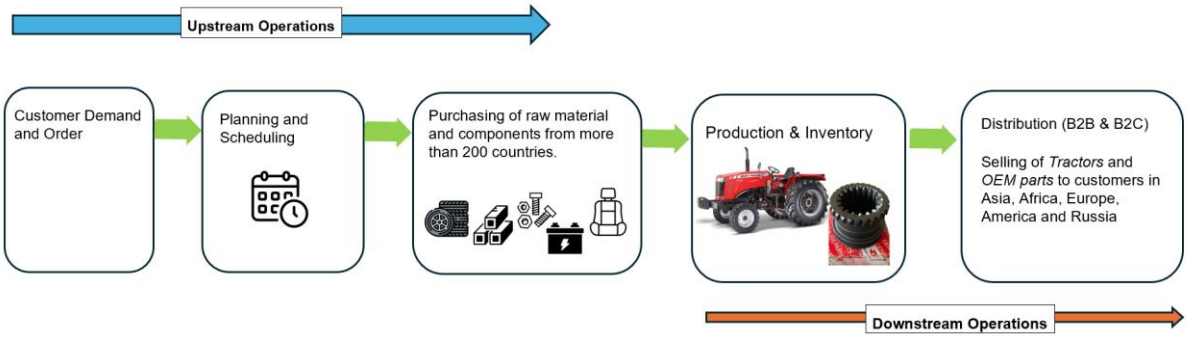
Currently, TAFE's key SSCM practices include sustainable sourcing, waste minimization, energy saving, respect for employee rights, and evaluating the environmental and social impacts of products and services throughout their life cycle, from raw material extraction to disposal (Life Cycle Assessment) (TAFE Sustainability report, 2024). Figure 2 represents the TAFE Supply Chain stages.

By adopting the Environmental, Social, and Governance (ESG) approach, TAFE identified ESG key risk areas and improved the scores, such as carbon footprint, energy efficiency, and waste management. Through the social screening approach, it improved the supplier's performance and reduced the negative social impacts. TAFE has initiated an iMaRQ

audit to ensure vendor quality control and Heijunka methodology in lean manufacturing to improve the on-time delivery.

Figure 2:

TAFE Supply Chain Stages (Source: Own Work)



TAFE needs to establish a comprehensive digital transformation and craft a robust supply chain sourcing strategy. TAFE is in the process of modernising its Robotics Process Automation (RPA) to improve supply and demand planning, and after-sales service management (TAFE Sustainability report, 2024).

2.5.2. RML (Rane Madras Limited) supply chain

Rane Madras Limited (RML), established in 1959, has developed into a prominent manufacturer of engine components, with an annual group turnover of INR 7,200 crores (approximately USD 870 million by 2024). RML sources raw materials from approximately 282 suppliers, both locally (from India) and across countries such as Malaysia, South Korea, and Germany, and sells its products to over 30 countries to several major automobile manufacturers such as Hyundai, Volkswagen, BMW, Volvo, Ashok Leyland, Daimler, John Deere, and Yamaha. The company holds four international standard certifications: ISO 9001:2015 - Quality Management, ISO 14001:2015 - Environmental Management, IATF 16949:2016 - Automotive Quality Management, and ISO 45001:2018 - Occupational Health and Safety Management (Rane Madras Limited, 2024). An overview of the manufacturing company RML and its supply chain is given in Table 3.

RML implements a range of SSCM practices, that include efficient warehouse management and Just-In-Time (JIT) delivery systems that help minimize excess inventory, reduce space utilization, and lower energy consumption. The company practices reverse logistics for returns, repairs, and recycling, supporting its sustainability goals. Transparent return and exchange policies build customer trust and help reduce waste.

Table 3:

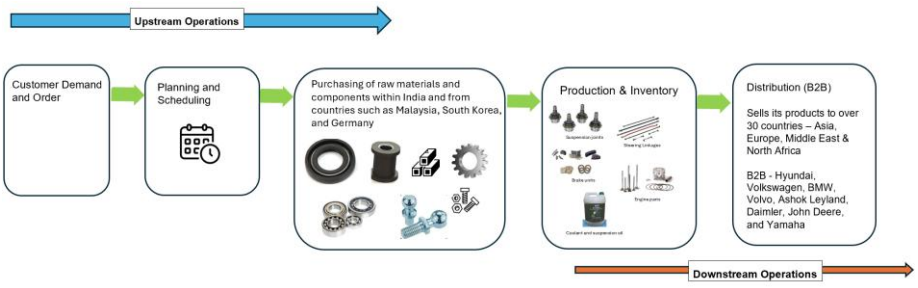
RML (Rane Madras Limited)

Company Overview	
Year Established	1959
Headquarters	Chennai, India
Industry	Automotive (Steering and Suspension Systems)
Annual Turnover	USD 820 million
Global Reach	Asia, Europe, Middle East, and North Africa.
Certifications	ISO 9001, ISO 14001, ISO 45001, IATF 16949
Source: RML Annual Report 2022-23	
Note: ISO - International Organization for Standardization; IAFT - International Automotive Task Force	
Supply Chain Overview	
Raw Material Sourcing	282 suppliers: domestic (India) and international (Malaysia, South Korea, Germany)
Key SSCM Practices	Just-In-Time delivery system, reduce excess inventory, Plastic minimization, Reverse logistics, Employee rights, and Ethical sourcing
Inventory Practices	Eco-friendly packaging, minimal plastics
Final Products	Pump assemblies, suspension joints, and engine components
ESG Targets	Net zero emission (2050), Zero landfill (2030), Water neutrality (2035)
Source: RML CSR report 2022	

By Total Quality Management (MTQ), RML has identified the weaker links and promoted the supplier's earlier involvement. JIT (Just-in-Time) and Kanban system improved the inventory management, material optimization, and waste reduction. Vendor Managed Inventory (VMI) improved the supply chain inventory, and the Plan-Do-Check-Act (PDCA) cycle facilitated continuous improvements. Lean Production System – Cross Company Study Support and Learning (LPS-CCSS) initiative in RML improved the SCM efficiency and customer satisfaction. Leadership Development improved the SCM team's efficiency for better performance. Figure 3 represents the RML Supply Chain stages.

Figure 3:

RML Supply Chain Stages (Source: Own Work)



Recently, COVID-19 has affected the Supply chain management in RML, and it has revived the digital technologies adopted in supply chain management for optimizing materials sourcing and logistics. It is establishing AI-powered tools to ensure materials quality, and inventory management (RML group-publication, 2017).

2.6. Research Questions

The review of the literature discussed in the previous section highlights several barriers that hinder the implementation of Sustainable Supply Chain Management (SSCM), which differ depending on the industry and geographical location. While developed countries have effectively implemented SSCM through established frameworks, progress in developing countries remains limited. The limited progress in developing countries necessitates context-specific research to address the gaps in SSCM implementation.

The research questions presented below are formulated based on SSCM practices observed in TAFE and RML. Data collected from these two manufacturing companies formed the basis for analysis by the Best Worst Method (BWM).

1) What is the current status of SSCM practices?
2) Which is the most significant internal barrier category among the four—organizational, cultural, communicational and psychological—for SSCM implementation?
3) What are the top 10 key barriers to SSCM implementation, among the 31 key barriers, each grouped under one of the four main categories identified in Research Question 2?

To address these research questions, a questionnaire survey was carried out to collect the data from 30 respondents, targeting 15 employees from each company (TAFE and RML) who are directly involved in supply chain operations. The survey responses collected from these 30 respondents were utilized for analyzing current SSCM practices, identifying the most significant internal barrier category, and the top 10 key barriers to SSCM implementation.

The following section provides a detailed description of the methodology utilized to address these three research questions.

3. Methodology

3.1 General Overview

The survey questionnaire for collecting the data consists of three sections that will specifically address the three research questions outlined in section 2.6. Table 4 provides an

overview of the methodology to answer the research questions of the study. For this study, the following definition and inferences are applied:

Best: Best is the parameter that is chosen by the respondents.

Worst: Worst is the parameter that is chosen by the respondents.

Most significant: The “Most significant” is the parameter that has the highest value, as determined by BWM analysis.

Least significant: The “Least significant” is the parameter that has the lowest value, as determined by BWM analysis.

Table 4:

Overview of the methodology

Research Question	Tools	Purpose
1) What is the current status of SSCM practices?	**Survey Questionnaire - Section 1** Based on *Survey question :* What is the current status of Sustainable Supply Chain Management (SSCM) practices in your organization?	Highlight the current status of SSCM practices
2) Which is the most significant internal barrier category among the four—organizational, cultural, communicational and psychological—for SSCM implementation?	**Survey Questionnaire - Section 2 - and calculations for BWM analysis** ***Survey questions:*** a) Which is the Best barrier category and the Worst barrier category b) Comparing Best to Others c) Comparing Others to Worst ***Calculations for BWM analysis:*** *d)* Final Weight calculation of each internal barrier category	Prioritize the most significant internal barrier category to SSCM implementation
3) What are the top 10 key barriers to SSCM implementation, among the 31 key barriers, each grouped under one of the four internal barrier categories identified in Research Question 2?	**Survey Questionnaire - Section 3 - and calculations for BWM analysis** ***Survey question*:** a) Rate each of 31 key barriers on a 5-point Likert scale ***Calculations and Ranking by BWM analysis*** b) Final weight calculation for each 31 key barriers	Prioritize the top 10 key barriers for SSCM implementation in the organization

Research Question 1 – *What is the current status of SSCM practices?*

Section 1 of the survey collected data on the status of Sustainable Supply Chain Management (SSCM) practices within the respondents' organizations. It incorporated 17 statements on SSCM practices. Respondents were asked to indicate their level of agreement with each statement based on their personal experience within the company.

Research Question 2 - *Which is the most significant internal barrier category among the four—organizational, cultural, communicational and psychological—for SSCM implementation?*

Section 2 of the survey collected data by asking respondents to identify the internal barrier category they considered the "Best" and the "Worst", followed by a pairwise comparison. It is necessary to remember, in this context, "Best" refers to the internal barrier category that is considered the most significant (in terms of delaying the initiation or progress) for SSCM implementation in the organization, compared with each of the other three categories. "Worst" refers to the internal barrier category that is considered the least significant for SSCM implementation in the organization. The Best-Worst method was applied to determine the final weights of each internal barrier to SSCM implementation (Rezaei, 2015). The internal barrier category with the highest final weight is identified as the "most significant", and the lowest final weight is identified as "least significant".

Research Question 3 - *What are the top 10 key barriers to SSCM implementation, among the 31 key barriers, each grouped under one of the four internal barrier categories identified in Research Question 2?*

Section 3 of the survey includes 31 key barriers that are grouped under four internal barrier categories. These 31 key barriers consist of thirteen key barriers under the Organizational category and six key barriers under each of the Cultural, Communicational, and Psychological categories. To identify the top 10 key barriers to SSCM implementation, a final weight is calculated for each barrier. This is done by multiplying the final category weight obtained from the BWM analysis (related to research question 2) by the individual score of each key barrier. The barriers are then ranked in descending order to rank the top 10 key barriers for SSCM implementation. This analysis provides a more in-depth examination of the four main internal barrier categories, allowing for a clearer understanding of how each is composed and how individual key barriers contribute to the overall SSCM implementation.

3.2 Highlight the current status of SSCM practices

To address research question 1—What is the current status of SSCM practices? each responder from TAFE and RML expresses an independent response to the 17 SSCM statements in the questionnaire. The response is recorded in terms of the level of agreement with each statement using a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The study uses the participants' responses to answer the first research question: What is the current status of SSCM practices? Table 5 summarises the 17 statements to record the responses for the SSCM practices in the respondent's organization.

Table 5:

Survey Questionnaire (Section 1) - What is the Current status of Sustainable Supply Chain Management (SSCM) practices in your organization?

No.	SSCM Statement	Response
1	Considering quality as the major criterion in selecting suppliers	Indicate on a five-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, 5 = Strongly Agree).
2	Promotes establishing a long-term relationship with its suppliers	
3	Includes its key suppliers in its planning and goal-setting activities	
4	Certifies its suppliers for the quality of the supplies	
5	Coordinate with the suppliers to solve problems.	
6	Periodically gets quality/service feedback from the customers.	
7	Strives to meet the customers' future expectations	
8	Shares a sense of fair play with its customers	
9	Informs in advance of the changing needs of its trading partners	
10	Exchanges information with trading partners to support business planning	
11	Information exchange with trading partners is adequate and reliable.	
12	Information exchange with trading partners is complete and accurate.	
13	Strives to reduce time wastage in operations	
14	Ask suppliers to deliver products faster.	
15	Sets up delivery locations near customers to speed up the supply process	
16	Waits to put together the final product until a customer places an order	
17	Each supply chain member has a clear responsibility and works in coordination.	

3.3 Prioritize the most significant internal barrier category to SSCM implementation

The second research question aims to find out "Which Internal barrier category among the four – organizational, cultural, communicational and psychological is the most significant for SSCM implementation?" This consists of survey questionnaire and calculations for BWM analysis as mentioned in table 4 row 2. The second research question is answered using

information obtained from specific questionnaire responses and calculations based on that information to determine the final weight of Best and Worst barrier category.

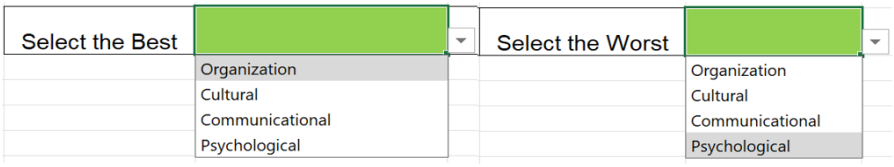
Survey questions:

a) Which is the "Best" barrier category and the "Worst" barrier category

In the survey questionnaire, the respondents marked the internal barrier category that they consider most significant for SSCM implementation ("Best"). Then respondents marked the internal barrier category that they consider least significant for SSCM implementation ("Worst"). This is represented in Figure 4.

Figure 4:

Selection of the Best and Worst category by respondents'



b) Comparing Best to Others

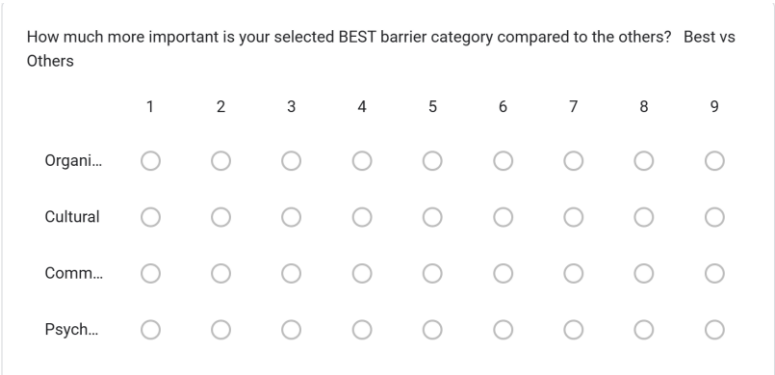
Respondents were asked to rate how much more important the Best category is compared to the others, using a simple scale from 1–9:

- A rating of 1 means the two categories selected for comparison are equally important.
- The numbers in between (2 to 8) show different levels of importance.
- A rating of 9 means the Best category is seen as much more important than the one it's being compared to.

Figure 5 shows the survey question where respondents rate how much more important (1 to 9 scale) their selected "Best" barrier category is, compared to the other three barrier categories. The best barrier category is the one, chosen by the respondents shown in Figure 4.

Figure 5:

Survey Question for Rating Best Barrier Category to Others



The vector representation for this step is denoted by a_{Bj} = (a_{Bi1}, a_{Bi2}, a_{Bi3}, a_{Bi4}), where "i" refers to the respondent and "j" corresponds to each of the four internal barrier categories: organizational, cultural, communicational, and psychological.

Similarly, this vector captured each respondent's "Best-to-Others" ratings, by comparing the selected Best barrier category with other four internal barrier categories.

Each element in this vector (a_{Bi1}, a_{Bi2}, a_{Bi3}, a_{Bi4}) shows how much more important the respondent think the Best barrier is, compared to the other four barrier categories.

c) Comparing Others to Worst

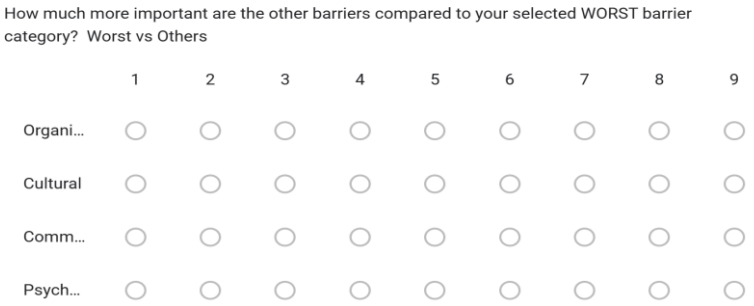
Similarly, the Worst barrier category is compared with each of the other three categories using a 9-point scale. Respondents rate how much more important each category is when compared to the "Worst," where:

- 1 indicates equal importance
- The numbers in between (2 to 8) show different levels of importance.
- and 9 indicates the other category is significantly more important.

Figure 6 shows the survey question where respondents rate how much more important the other three internal barrier categories are when compared with the Worst barrier category.

Figure 6:

Survey Question for Rating Others to Worst Barrier Category



The vector representation for this step is $a_{Wj} = (a_{Wi1}, a_{Wi2}, a_{Wi3}, a_{Wi4})$ where "i" refers to the respondent and "j" corresponds to each of the four internal barrier categories: organizational, cultural, communicational, and psychological.

Similarly, this vector captured each respondent's "Others-to-Worst" ratings by comparing the four internal barrier categories with the selected Worst barrier.

Each element in this vector ($a_{W1}, a_{W2}, a_{W3}, a_{W4}$) show how much more important the respondent considers each barrier category to be, in comparison to the Worst barrier category.

Calculations for BWM analysis:

d) Final Weight Calculation of each internal barrier category

Finally, to address research question 2 – Which is the most significant internal barrier category among the four—organizational, cultural, communicational and psychological—for SSCM implementation? - the Best Worst Method (BWM) analysis was applied. This approach will calculate final weights that will help determine which internal barrier category is most significant for SSCM implementation. These weights were derived from the response vectors obtained from the questionnaire, as described earlier in points b) and c).

The final weight for each internal barrier category is calculated on a scale from 0 to 1, indicating its significance. Values are interpreted in descending order—the higher the value, the greater the significance.

The final weight of each barrier category is calculated based on the comparison made in the previous steps b and c.

b. Comparing Best to Others a_{Bj} = $(a_{Bi1}, a_{Bi2}, a_{Bi3}, a_{Bi4})$,

c. Comparing Others to worst: $a_{Wj} = (a_{Wi1}, a_{Wi2}, a_{Wi3}, a_{Wi4})$

For calculating the final weight, a linear programming model is applied to minimize the maximum difference between the values obtained from respondents' pairwise comparisons from both the Best-to-Others and Others-to-Worst steps. By reducing this difference, the model ensures that the results are as reliable and consistent as possible. The mathematical formula for calculating the final weight of each internal barrier category is:

$$|W_B - a_{Bj}\, W_j| \leq \xi$$

$$|W_j - a_{Wj} W_w| \leq \xi$$

Where:

a_{Bj} – Rating of Best barrier category compared to other categories (j)

a_{Wj} – Rating of other barrier categories (j) compared to Worst barrier category

W_B – Final Weight of Best barrier category

W_w – Final Weight of Worst barrier category

W_j – Final Weight of barrier category *j (* where *j* represents one of the four internal barrier category)

ξ – Consistency ratio. The lower the value, the more reliable the results are

Figure 7:

Final Internal barrier Category Weight results

Final Weights	Organizational	Cultural	Communication	Psychological

The calculation of the final weight was implemented using Excel-based computation tools to facilitate automated processing of the response data. By solving the mathematical formula, we determine the final weights for each internal barrier category, thereby answering Research Question 2 - Which is the most significant internal barrier category among the four—organizational, cultural, communicational and psychological—for SSCM implementation? Based on the category weight, the internal barrier category with the highest final weight is considered as the most significant for SSCM implementation.

3.4 Prioritization of top 10 key barriers for SSCM implementation in the organization

To address research question 3—*What are the top 10 key barriers to SSCM implementation, among the 31 key barriers, each grouped under one of the four main categories identified in Research Question 2?* This consists of the survey questionnaire and analysis as mentioned in table 4 row 3. The third research question is addressed through the responses to 31 key barriers in section 3 of the survey.

Survey questions:

a) Rate each of 31 key barriers on a 5-point Likert scale

Each responder from TAFE and RML expressed an independent response to the 31 key barriers in section 3 of the questionnaire. It consists of thirteen key barriers under the Organizational category and six key barriers under each of the Cultural, Communication, and Psychological categories. The response is recorded in terms of the level of agreement to each key barrier using a five-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The analysis based in this data aims to explore these main categories in greater depth by examining their underlying key barriers. Table 6 summarises the statements to record responses to identify 31 key barriers for the SSCM implementation in the respondent's organization.

Table 6: *Survey Questionnaire (Section 3) - Rate each of the 31 key barriers on a 5-point Likert scale*

Barrier Category	Barrier Statement	Barrier Code	Response
Organizational Barriers	Complex structure of SC (SSCM) in your organization	OB1	Indicate on a five-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neither Agree nor Disagree, 4 = Agree, 5 = Strongly Agree).
	Insufficient commitment from top management	OB2	
	Lack of an effective model to guide SSCM implementation	OB3	
	Restrictive company policies for product/process management	OB4	
	Lack of inter-organizational cooperation and coordination	OB5	
	Opposition to change	OB6	
	Non-standardized performance metrics	OB7	
	Reduced employee involvement and participation	OB8	
	Lack of resource sharing	OB9	
	Unwillingness to share risks	OB10	
	Lack of financial gain	OB11	
	Unwillingness to spend on training for mid-level executives	OB12	
	Lack of corporate social responsibility practices	OB13	
Cultural Barriers	Insufficient societal pressure	CulB1	
	Fear of extra workload and loss of flexibility	CulB2	
	Lack of entrepreneurial skills and thinking outside the box	CulB3	
	Negative attitudes towards sustainability concepts	CulB4	
	Popularity only in traditional technologies	CulB5	
	Mistrust among employees and supply chain partners	CulB6	
Communicational Barriers	Lack of Inter-departmental co-operation in communication	ComB1	
	Lack of information technology support for ERM	ComB2	
	Difficulty in understanding and interpreting the outcomes of the RM process	ComB3	
	Lack of awareness of environmental impacts among employees	ComB4	
	Lack of understanding regarding market competition	ComB5	
	Lack of knowledge and training on reverse logistics	ComB6	
Psychological Barriers	Fear of Conflict between top and mid-management faculties	PsyB1	
	Lack of Self-Confidence among mid-management faculties	PsyB2	
	Fear of cost escalation	PsyB3	
	Lack of Motivation	PsyB4	
	Resistance to Feedback	PsyB5	
	Fear of customer dissatisfaction	PsyB6	

Calculation and Ranking by BWM analysis:

b) Final weight calculation for each 31 key barriers.

Finally, to address research question 3 - *What are the top 10 key barriers to SSCM implementation, among the 31 key barriers, each grouped under one of the four main categories identified in Research Question 2?* the Best Worst Method (BWM) analysis was applied. This approach will calculate the final weights of each key barrier. These weights were derived from the response obtained from the questionnaire. The final weight calculated in this step is different from the final weight calculated from the four internal barrier categories in subsection 3.3 (d).

For this, we calculate this formula:

Final Weight of Each Key Barrier = Internal Barrier category weight × Normalization score

Where:

Internal Barrier category weight: BWM-derived weight of its category, which we obtained from research question 2

Normalization score: Sum of all averages of 31 key barriers / Average score of each key barrier

If we only rank the individual barriers without considering their final category weight, the result will be misleading. So, to ensure balanced and meaningful prioritization, we calculated the final weight by multiplying each barrier's normalization score by its internal barrier category weight, which we obtained from research question 2. By doing so, we ensured that the results are consistent and reliable. This helps managers and decision-makers focus on solving the problems that truly impact SSCM practices.

Based on the final weight obtained from the above step, ranking was given to all 31 key barriers, starting with the barrier with the highest final score. The first 10 key barriers with final weight in descending order are identified as the top 10 key barriers. These interpretations answer the Research Question 3—*What are the top 10 key barriers to SSCM implementation, among the 31 key barriers, each grouped under one of the four main categories identified in Research Question 2?*

4. Results

4.1 Respondents' details

This section does not contribute directly to the analysis, but it adds credibility and validity to the data by ensuring that the responses were collected from professionals working in the supply chain department. A total of 30 respondents were surveyed, comprising 15 respondents from TAFE and 15 respondents from RML. Table 7 presents the descriptive statistics of the respondents from TAFE and RML.

Respondents are distributed almost equally in all three categories: managerial, supervisory, and executive levels. It is observed that 53.3% and 46.7% of the respondents from these two manufacturing companies, TAFE and RML, are post-graduates, and have more than five years of experience respectively

The respondents who provided the data for the study are professionals working in various positions, such as managers, assistant managers, supply chain leads, analysts, and other experienced staff. These respondents work in different key departments, including supply chain, logistics, purchasing, and production. The information provided by these professionals from the various sectors strengthens the overall quality and reliability of the data collected on SSCM.

Table 7:

Descriptive statistics of the responders from TAFE and RML

Respondents' Details (n=30)			
	TAFE	**RML**	**Total**
Age group (Yrs)			
20 – 30	8	7	15 (50.0%)
31 – 40	3	5	8 (26.7%)
41 - 50	4	3	7 (23.3%)
Qualification			
Diploma	1	1	2 (6.7%)
Graduate	7	5	12 (40.0%)
Postgraduate	7	9	16 (53.3%)
Experience			
< 5 yrs	7	9	16 (53.3%)
> 5 yrs	8	6	14 (46.7%)
Responders' Position			
Manager	3	2	5 (16.7%)
Assistant Manager	2	3	5 (16.7%)
Supply Chain Lead	2	2	4 (13.3%)
Supply Chain Business Administrator	0	3	3 (10.0%)

Table 7 (continued):

Descriptive statistics of the responders from TAFE and RML

Supply Chain Management Specialist	1	0	1 (3.3%)
Logistics Analyst	2	0	2 (6.7%)
Supply Chain Assistant	5	5	10 (33.3%)
Current phase of SSCM in your organization *Multiple Choice*			
We have recently implemented Sustainable practices in our supply chain department	0	2	2 (6.7%)
Major Parts of our supply chain have implemented sustainable practices	2	8	10 (33.3%)
Sustainable practices have been implemented throughout the entire supply chain	13	5	18 (60%)

We asked participants about the SSCM technologies they currently use in their organizations. Most of them reported using Inventory Management Software (67%), Warehouse Management Systems (63.3%), and Supply Chain Analytics Platforms (60%). This indicates that the respondents are familiar with essential software tools that support efficient SSCM in manufacturing industries.

Regarding the current phase of SSCM implementation, 18 (60%) respondents indicated that sustainable practices have been implemented throughout the entire supply chain, while 10 (33.33%) respondents reported partial implementation. Only 2 (6.67%) respondents stated that their organizations are in the early stages of adoption. Together, these responses show that SSCM adoption varies in depth across the two organizations.

4.2 Highlight Current Status of SSCM Practices in TAFE and RML

RQ1 - *What is the current status of SSCM practices?*

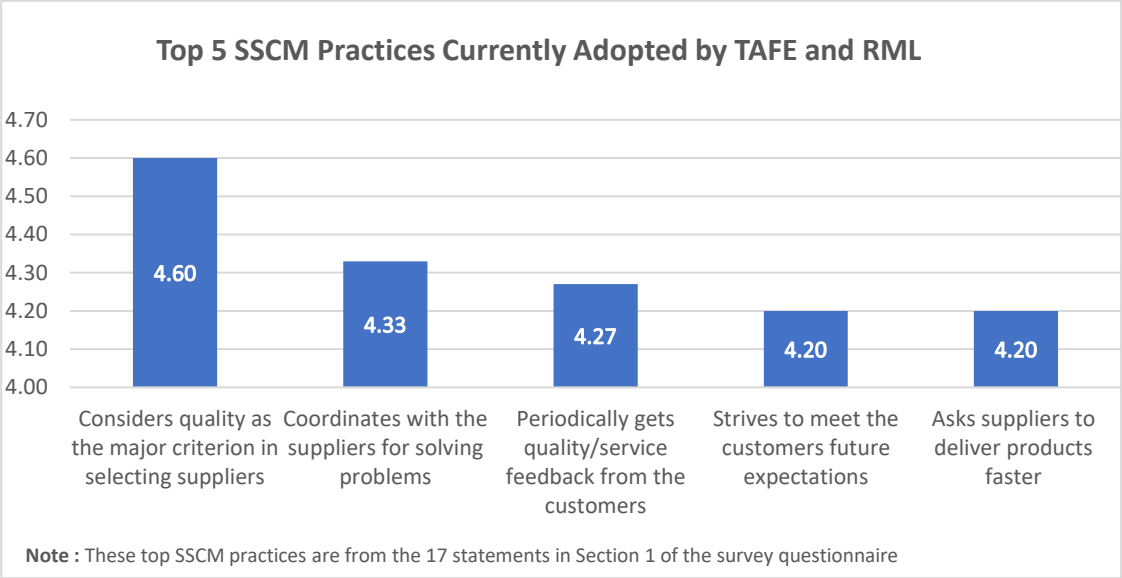
This research question assesses the overall status of SSCM implementation in TAFE and RML. This assessment identified which sustainable practices are most widely followed in these organizations. To do this, respondents rated 17 SSCM-related statements on a five-point Likert scale as mentioned in section 3.2. The study selects the five practices with the highest

average score to illustrate the areas where TAFE and RML demonstrate the strongest dedication, even though other practices also received good ratings overall.

Figure 8 displays the top five SSCM practices used in TAFE and RML based on the average scores of the respondents to the 17 SSCM statements. These include choosing suppliers mostly on the basis of quality standards (4.60), working closely with suppliers to address problems (4.33), regularly gathering customer input (4.27), aiming to meet future customer expectations (4.20), and putting pressure on suppliers to deliver more quickly (4.20). The findings from the analysis facilitate TAFE and RML management in identifying and developing strategies for further improving these five SSCM practices. Management will also plan to allocate sufficient funds for improving these SSCM practices in the organization.

Figure 8:

Top Five SSCM Practices used in TAFE and RML



4.3 Prioritization of the most significant internal barrier category to SSCM implementation in TAFE and RML

RQ2 *– Which is the most significant internal barrier category among the four – organizational, cultural, communicational, and psychological – for SSCM implementation?*

To answer this research question, we have analysed the survey responses and applied the Best-Worst Method (BWM) solver to examine how employees at TAFE and RML perceive and prioritize major SSCM internal barrier categories. This analysis enables us to identify the

barrier categories with the most significant internal barrier categories for SSCM implementation.

Survey results:

a) The 'Best' and 'Worst' barrier category: TAFE and RML

This step involves collecting information directly from the respondents, identifying the Best and the Worst barrier category based on the individual's experience in TAFE or RML. Each respondent marked his/her response to each of the barrier categories on a 5-point Likert-scale in the questionnaire. The frequency distribution based on the responses is shown in Table 8.

Table 8:

Selection of the Best and the Worst barrier category by the respondents (n=30)

Internal Barrier Category	Selected as Best		Selected as Worst	
	n	%	n	%
Organizational	19	63.3	2	6.7
Cultural	4	13.3	7	23.3
Communicational	5	16.7	3	10.0
Psychological	2	6.7	18	60.0

It is observed that 19, 4, 5, and 2 of the 30 respondents identified organizational, cultural, communicational, and psychological barriers, respectively, as the Best internal barrier category for SSCM implementation. Similarly, 2, 7, 3, and 18 of the 30 respondents identified organizational, cultural, communicational, and psychological barriers, respectively, as the Worst internal barrier category for SSCM implementation (Table 8).

Based on these findings, the organizational barrier is selected by the respondents as the "Best" barrier category, and the psychological barrier as the "Worst" barrier category for SSCM implementation in TAFE and RML. "Best" in this context, refers to the internal barrier category that is considered the most significant (in terms of delaying the initiation or progress) for SSCM implementation in the organization, compared with each of the other three categories. "Worst" refers to the internal barrier category that is considered the least significant for SSCM implementation in the organization.

b) Final rating of Best to Others: TAFE and RML

In the survey, each of the 30 respondents marked their relative scores for the Best internal barrier category to the other internal barrier categories, as mentioned in Figure 5. The median value of the 30 respondents was taken to compile the results. It is observed from the responses to the survey that the organizational barrier is considered 4, 3, and 8 times more significant than cultural, communicational, and psychological barriers, respectively (Table 9).

Table 9:

Relative scores : Best to Others

Internal Barrier category	**Best to Others (Median response*)**			
	Organizational	Cultural	Communicational	Psychological
Organizational	1	4	3	8

Note: Median response in 1 – 9 Scale*

c) Final rating of Others to Worst: TAFE and RML

Similarly, in the survey, each of the 30 respondents marked their relative score for the other internal barrier category to the Worst internal barrier category, as mentioned in Figure 6. The median value of the 30 respondents was taken to compile the results. It is observed from the responses to the survey that the organizational barrier is considered 8 times more significant than the psychological barrier, the cultural barrier 5 times, and the communicational barrier 4 times more significant than the psychological barrier. respectively (Table 10).

Table 10:

Relative scores : Others to Worst

Internal Barrier category	**Others to Worst (Median response*)**			
	Organizational	Cultural	Communicational	Psychological
Psychological	8	5	4	1

Note: Median response in 1 – 9 Scale*

BWM analysis result:

d) Final Weight calculation of each internal barrier category: TAFE and RML

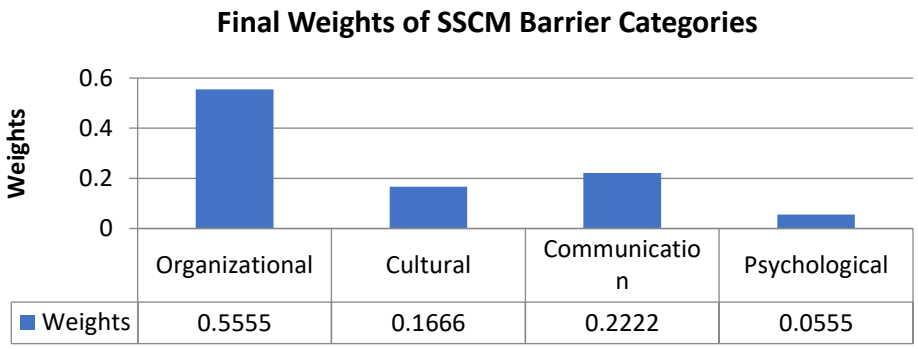
In order to answer Research Question 2—*Which is the most significant internal barrier category among the four – organizational, cultural, communicational, and psychological – for SSCM implementation?* the Best Worst Method (BWM) is utilized. By applying BWM, the weights of the four internal barriers are calculated based on the scores given by the respondents in the survey questionnaire. The details provided in the previous steps b) and c) form the basis for calculating the weight of the four barrier categories.

The final weight for each internal barrier category is calculated by BWM analysis on a scale from 0 to 1, indicating its significance. Values are interpreted in descending order—the higher the value, the greater the significance for SSCM implementation. The barrier category with the highest value by BMW analysis is confirmed as the "Most significant" and the lowest value as the "Least significant" for SSCM implementation.

The results show that organizational barriers received the highest weight of 0.5555, while communicational barriers, cultural barriers, and psychological barriers received weights of 0.2222, 0.1666, and 0.0555, respectively. The calculated weights by BWM analysis show that organizational barriers are by far the most significant internal barriers to SSCM implementation in TAFE and RML. Figure 10 visually represents the final weights assigned to each SSCM internal barrier category using the BWM analysis.

Figure 9:

Final Weight of each Barrier Category Based on BWM Analysis



These findings suggest that for South Indian manufacturing companies—TAFE and RML, addressing the organizational barrier category should be the top priority for strengthening

sustainable supply chain management. In contrast, respondents view psychological barrier as least significant.

4.4 Ranking of Key Barriers of SSCM in TAFE and RML

RQ3 – *What are the top 10 key barriers to SSCM implementation, among the 31 key barriers, each grouped under one of the four main categories identified in Research Question 2?*

To answer research question 3, we applied the BWM to analyse the responses to 31 key barriers by the employees of the two manufacturing industries, TAFE and RML. This analysis facilitates identifying the top 10 key barriers for SSCM implementation in their organizations.

Survey results:

a) Rate each of the 31 key barriers on a 5-point Likert scale: TAFE and RML

First, the respondents marked their independent response to each of the 31 key barriers on a five-point Likert scale in the survey questionnaire. The data of the 30 respondents was compiled to calculate the average score and the normalization score.

Responses in a Likert-scale cannot be used for direct comparison without appropriate adjustment. Normalization converts the average score obtained from the data from Likert-scale to a standardized value for fair comparison. It is a preprocessing step to the BWM analysis that ensures that the decision-making process is based on comparable standardized data and the results obtained from these comparisons are accurate and reliable.

Table 11 shows the average score for each of 31 key barriers to SSCM implementation. It is observed that among the Organizational barriers, "*OB1 – Complex Structure of SC (SSCM) in your organization"* has the highest score 3.6333, and the highest normalization score 0.0384; "*OB12* – Unwillingness to spend on training for mid-level executives" has the lowest average score 2.0333 and the lowest normalization score 0.0215.

Among the Communication Barriers, "*ComB5 – Lack of understanding regarding market competition"* has the highest average score 3.2000", while "*ComB1 – Lack of inter-departmental co-operation in communication*" and "*ComB3 – Difficulty in understanding and interpreting the outcomes of the RM process*" shared the highest normalization score 0.0356. Conversely, ComB3 showed the lowest average score 2.2000, and *"ComB4 – Lack of awareness of environmental impacts among employees*" had the lowest normalization score 0.0265.

For the cultural barriers, "*CulB2 – Fear of extra workload and loss of flexibility"* had the highest average score 3.5000, while *"CulB4 – Negative attitudes towards sustainability*

concepts" had the lowest average score 2.5000. In terms of normalization score, *"CulB5 – Popularity only in traditional technologies"* ranked the highest 0.0339, whereas *"CulB3 – Lack of entrepreneurial skills and thinking outside the box*" ranked the lowest 0.0233.

Among the Psychological barriers, *"PsyB6 – Fear of customer dissatisfaction"* has the highest average score 3.4667 and the highest normalization score 0.0367; *"PsyB2 – Lack of self-confident among mid-management faculties"* has the lowest average score of 2.9000 and the lowest normalization score of 0.0307.

These calculated normalization scores provide a standardized to calculate the final weight in the next step.

Calculation and Ranking by BWM analysis:

b) Final weight calculation for each 31 key barriers: TAFE and RML

In order to address Research Question 3 — *"What are the top 10 key barriers to SSCM implementation, among the 31 key barriers, each grouped under one of the four main categories identified in Research Question 2?"* — the Best-Worst Method (BWM) is applied. This method determines the final weights for each of 31 key barriers based on the normalization score calculated from the average score. This average score was obtained from the responses provided in the questionnaire, as outlined previously in Table 6.

A general analysis of the weights of the barriers within each main category shows the following result.

Organizational barriers (OB): The highest final weight is for *OB1 – Complex structure of SC (SSCM) in your organization* (0.02136), while the lowest is for *OB11 – Lack of financial gain* (0.00823).

Communication barriers (ComB): The highest final weight is for *ComB2 – Lack of information technology support for ERM* (0.01861), and the lowest is for *ComB4 – Lack of awareness of environmental impacts among employees* (0.00588).

Cultural barriers (CulB): The highest final weight is for *CulB5 – Popularity only in traditional technologies* (0.00564), and the lowest is for *CulB3* – Lack of entrepreneurial skills and thinking outside the box (0.00388).

Psychological barriers (PsyB): The highest final weight is for *PsyB6 – Fear of customer dissatisfaction* (0.00204), and the lowest is for *PsyB2 – Lack of self-confidence among mid-management faculties* (0.00170).

Based on the calculated final weight, a ranking was allotted to each key barrier (Table 11) to answer the research question 3 – "*What are the top 10 key barriers to SSCM implementation, among the 31 key barriers, each grouped under one of the four main categories identified in Research Question 2?"*. As mentioned in the barrier category, the higher the rank higher the importance in terms of its impact on SSCM implementation. Table 11 depicts the ranking of all 31 key barriers by final weight, and Figure 11 presents the top 10 key barriers ranked by final weight.

Table 11:

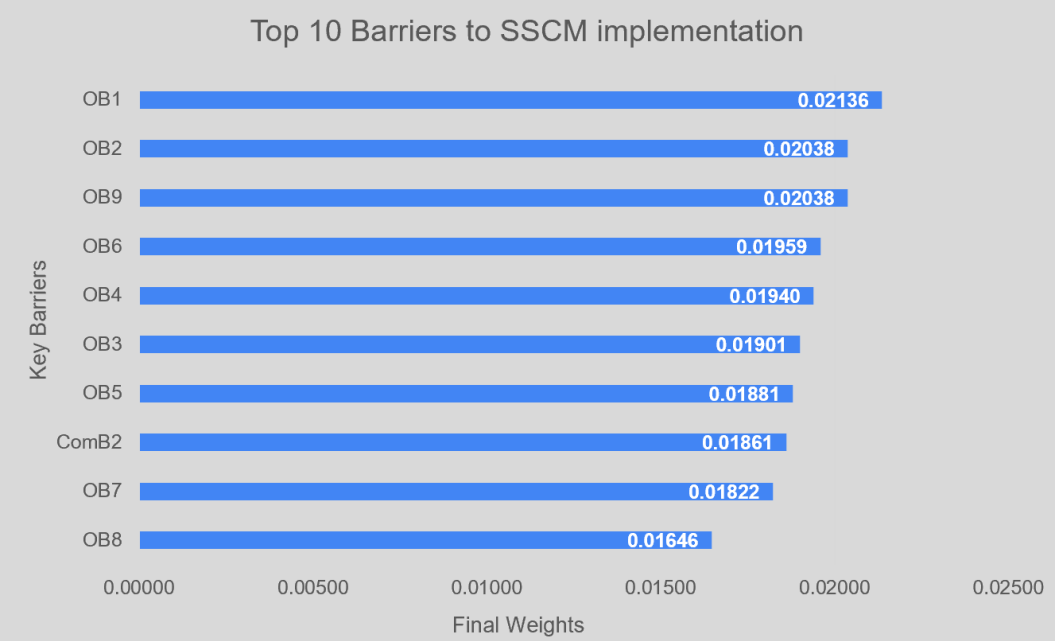
Weight of SSCM Barriers and the Ranks Across All Categories

Barrier Code	Average Score	Normalization Score	Final Weight	Rank Order
OB1	3.6333	0.0384	0.02136	1
OB2	3.4667	0.0367	0.02038	2
OB3	3.2333	0.0342	0.01901	6
OB4	3.3000	0.0349	0.01940	5
OB5	3.2000	0.0339	0.01881	7
OB6	3.3333	0.0353	0.01959	4
OB7	3.1000	0.0328	0.01822	9
OB8	2.8000	0.0296	0.01646	10
OB9	3.4667	0.0367	0.02038	3
OB10	2.8000	0.0296	0.01646	11
OB11	3.1667	0.0370	0.00823	14
OB12	2.0333	0.0215	0.01195	13
OB13	2.5667	0.0272	0.01509	12
ComB1	3.0333	0.0356	0.00792	15
ComB2	3.1333	0.0335	0.01861	8
ComB3	2.2000	0.0356	0.00792	16
ComB4	2.5667	0.0265	0.00588	19
ComB5	3.2000	0.0346	0.00768	17
ComB6	2.4333	0.0321	0.00713	18
CulB1	3.3667	0.0321	0.00535	22
CulB2	3.5000	0.0332	0.00552	21
CulB3	3.3667	0.0233	0.00388	25
CulB4	2.5000	0.0272	0.00452	23
CulB5	3.2667	0.0339	0.00564	20
CulB6	3.0333	0.0257	0.00429	24
PsyB1	3.2333	0.0342	0.00190	27
PsyB2	2.9000	0.0307	0.00170	31
PsyB3	3.2333	0.0342	0.00190	28
PsyB4	3.0000	0.0317	0.00176	29
PsyB5	2.9667	0.0314	0.00174	30
PsyB6	3.4667	0.0367	0.00204	26

From the ranking, we can see that nine of the top 10 barriers to SSCM implementation fall under the organizational category, and one falls under the communication category. This finding underscores the substantial impact of internal management, leadership commitment, and operational structure on the successful implementation of SSCM practices within manufacturing firms.

Figure 10:

Top 10 Key Barriers to SSCM Implementation



Note: OB1 - Complex structure of SC (SSCM) in your organization ; **OB2** - Insufficient commitment from top management; **OB9** - Lack of resource sharing; **OB6** - Opposition to change; **OB4** - Restrictive company policies for product/process management; **OB3** - Lack of an effective model to guide SSCM implementation; **OB5**- Lack of inter-organizational cooperation and coordination; **COMB2** - Lack of information technology support for ERM; **OB7** - Non-standardized performance metrics; **OB8** - Reduced employee involvement and participation

The top three barriers are *"OB1—Complex structure of SC (SSCM) in your organization",* "*OB2—Insufficient commitment from top management",* and *"OB9—Lack of resource sharing"* highlight weaknesses in leadership and internal alignment. Both TAFE and RML need to improve their leadership qualities, with top management members, playing a more active role in supporting and providing the needed resources to strengthen the SSCM. Since OB1- Complex structure of SC (SSCM) received the highest rating among all the barriers, it is essential for both TAFE and RML to take steps towards simplifying the supply chain structure to enable more effective SSCM implementation. We consider these barriers to be the first line of defense for SSCM in manufacturing industries in South India.

Notably, the results indicate that one communication barrier, "ComB2 - Lack of information technology support for Enterprise Resource Management", emerges within the top ten barriers. This alarms the management that communication barriers are also gaining

significance in SSCM implementation in manufacturing industries. Prioritization of these key barriers enhances the decision-making process of the organization and cultivates a more supportive environment for the implementation of SSCM in TAFE and RML.

The study also indicates that two categories, cultural and psychological barriers, are not significant barriers for these manufacturing industries. It is clear from Table 10 that the last 10 managerial barriers (ranks 21 to 31) are from the categories of cultural and psychological barriers. From this analysis and rankings, it is clear that South Indian manufacturing companies like TAFE and RML, aiming to enhance their sustainability efforts, should first address core managerial inefficiencies while simultaneously strengthening external coordination to support long-term SSCM success.

5. Conclusion

This chapter concludes the study by summarizing the key findings related to the research questions framed for the study. It highlights the practical and academic contributions of the research while reflecting on the overall research process. It will also outline the study's limitations and propose opportunities for future research.

Sustainable Supply Chain Management (SSCM) has become an integral part of the manufacturing industries in developed countries. However, in developing countries, SSCM implementation is in a slow phase due to several barriers. This study aimed to examine the SSCM status, prioritize the major internal barrier categories, and rank the 31 key barriers for SSCM implementation in South Indian manufacturing companies, with a particular focus on TAFE and RML. We have adopted the Best and Worst Method (BWM) for ranking the barriers.

In response to the first research question on SSCM status, as assessed through 17 statements, the study findings show that five SSCM practices stand out as very significant. These include choosing suppliers mostly on the basis of quality standards (4.60), working closely with suppliers to address problems (4.33), regularly gathering customer input (4.27), aiming to meet future customer expectations (4.20), and putting pressure on suppliers to deliver more quickly (4.20). These findings indicate that the top management needs to focus on these five SSCM practices to improve the overall SSCM implementation in the organization.

Regarding the second research question, results from the Best Worst Method (BWM) analysis indicate that, among the four internal barrier categories, organizational barriers are the most significant barrier among the four internal barrier categories for SSCM implementation. In addressing the third research question, the study revealed that among the top ten key barriers, nine key barriers are from the organizational category and one key barrier

is from the communicational category. This again emphasizes the importance of the organizational barriers for SSCM implementation within these manufacturing companies.

Our findings from this study align with other authors who included internal barriers in their research. However, these authors had applied a different Multi-Criteria Decision Making (MCDM) analysis method in their studies. Through the Interpretive Structural Modelling (ISM) approach, Rakesh et al. (2021) have found that a lack of commitment from top management as one of the top organizational barriers to SSCM implementation in the field of electronics manufacturing industries in India.

Similarly, applying the ISM-MICMAC method, Khandelwal et al. have identified that a lack of support and commitment from top management within the organization is one of the top barriers for SSCM implementation in the plastic manufacturing industries in India (Khandelwal, 2020). In addition, by collecting data from 10 automobile manufacturing industries in India and applying the AHP method for analysis, Jamwal et al. observed that the economic barrier is one of the significant internal barriers for SSCM implementation (Jamwal, 2020).

The findings from the present study contribute to the growing interest in Sustainable Supply Chain Management (SSCM) research, particularly within the context of South Indian manufacturing industries. Previous studies have examined SSCM barriers in India by employing various analytical methods. Despite its contributions, this research acknowledges certain limitations. First, the research was based on data collected from only two manufacturing companies, TAFE and RML, located in the same city, Chennai, which may limit the ability to generalize the findings to the broader manufacturing sector. Second, we utilized a structured questionnaire to gather data online; however, our engagement with respondents was limited, preventing us from obtaining deeper insights into the identified barriers. Third, due to time constraints, we limited the sample (responders) to thirty. Nevertheless, the study provides meaningful insights within its defined scope and offers a foundation for broader future investigations in South-Indian manufacturing industries.

In the present study, we have applied BWM, and the reasons for applying and its major advantages are outlined in subsection 3.3. The study also examined the internal barriers categories: organizational, communication, cultural, and psychological. In developing countries, management plays a critical role, and management bears the primary responsibility for the implementation of SSCM in the organization. Our findings are particularly relevant to the context of developing countries, specifically within the manufacturing industries. By applying the BWM, we introduce a structured and practical approach for prioritizing barriers in regions where such applications have been limited. These insights are helpful for future researchers who plan to work in similar industries or regions.

Our suggestion for future researchers would be to expand the scope by including a larger and more diverse sample of manufacturing companies across different regions of South India. A broader dataset would enable strong generalization and comparative insights across different manufacturing sectors and wide geographic areas. Additionally, though BWM is a recent MCDM method, integrating the BMW method with techniques such as DEMATEL and AHP will provide a more comprehensive view of the interrelationships between barriers.

In conclusion, this research examined the 31 key barriers to SSCM implementation in South Indian manufacturing industries, using the Best-Worst Method (BWM) to prioritize these barriers based on employee perspectives at TAFE and RML. The findings revealed that organizational barriers remain the most significant barrier, particularly those related to leadership commitment, performance measurement, and internal coordination. Despite limitations in sample size and scope, the study provides practical insights that future researchers and industry practitioners can build upon. Overall, the research enhances understanding of SSCM implementation in developing economies and offers direction for further exploration in this evolving field. To explore further, several studies, particularly those focusing on managerial barriers, are needed in India across the manufacturing sectors.

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