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BUILDING RESILIENT SUPPLY CHAINS: RISK ANALYSIS TECHNIQUES FOR SUPPORTING INNOVATION IN PROCUREMENT

Ashish Dhongde

Procurement and Supply Chain Resilience Leader, Building Resilient Supply Chains: Risk Analysis Techniques for Supporting Innovation in Procurement

ashish.dhongde@unilever.com

Abstract

In the time of global disruptions, organizations face a significant challenge in trying to maintain operations and innovate their procurement processes. Advanced risk analysis techniques have been used to address vulnerabilities and enhance decision-making in supply chain management. This study integrates predictive analytics, machine learning models, and scenario-based simulations into a comprehensive framework for identifying, assessing, and mitigating risks across procurement networks. The key areas of focus are supplier risk evaluation, demand-supply balancing, and contingency planning. The proposed approach emphasizes collaboration, agility, and sustainability as cornerstones of resilient supply chain design. Case studies across industries such as manufacturing, healthcare, and technology illustrate the practical application of these techniques, highlighting their role in driving innovation, reducing costs, and ensuring continuity amidst uncertainties. The findings contribute toward the development of procurement strategies that help organizations respond proactively to changes in market dynamics and external threats.

Keywords: Supply Chain Resilience, Risk Analysis Techniques, Procurement Innovation, Predictive Analytics, Scenario-Based Simulations and Sustainability.

1. Introduction

Modern economies live and thrive on global supply chains that provide the lifeline of businesses through the sourcing, production, and delivery of goods and services across extensive networks. Unfortunately, growing complexity and dependence in these supply chains have created vulnerabilities for all these types of risks - geopolitical tension, economic instability, natural disaster, or cyberattacks - to come knocking at any point in time. Disruptions, such as the Covid-19 pandemic, Russia-Ukraine conflict, and increasingly heated trade wars have, therefore brought out these inherent vulnerabilities in global supply networks against the risk that companies should rethink in managing it through different approaches [1], procurement strategy. These factors have propelled organizations into developing resilient supply chains which can face shocks, without operational discontinuity.

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Supply chain resilience is the ability of a supply chain to anticipate, absorb, and recover from disruption with the least damage possible in order to maintain continuity amid unpredicted events. Traditional risk management approaches for supply chains tend to be more reactive, dealing mainly with the control of damage once disruption happens. However, as the frequency and intensity of supply chain disruptions increase, focus is shifting to proactive, data-driven strategies that mitigate risks while enhancing operational efficiency and driving innovation in procurement processes. It is, therefore, vital for organizations looking to remain competitive in an age of constant change and uncertainty [2].

Procurement, one of the pillars of supply chain management, has become the critical link to building resilience. This would involve the procurement of raw materials, components, and services along with supplier relationship and contract management. Advanced technologies, data-driven decision-making, and innovative procurement practices can make all the difference in building up the resilience of a supply chain. For example, predictive analytics, machine learning, and blockchain technologies are now increasingly used to identify possible vulnerabilities, optimize supplier networks, and ensure transparency and traceability in supply chains. These technologies enable organisations to better respond to disruptions but take advantage of opportunities for innovation that create long-term value [3].

The risk analysis techniques play an essential role in building a resilient supply chain and fostering innovation in procurement. Risk analysis involves identifying risks and the probability and impact assessment; however, it also deals with mitigation and management strategies of risks. These techniques range from qualitative approaches, such as expert judgment and scenario planning, to quantitative approaches, including statistical modeling and simulation. The advances in predictive analytics and artificial intelligence have further improved the accuracy and efficiency of risk analysis, allowing organizations to forecast disruptions and assess their potential impact on supply chain operations [4].

The concept of resilience goes beyond just risk mitigation, involving adaptability and agility. Resilience in the supply chain is marked through its agility to adapt faster to a change in condition, by reconfiguring supplier networks, reallocating resources, or leveraging alternative transport routes. This adaptability is critical in procurement organisations, considering the changing dynamics, regulatory demands, and other expectations by customers. By opening up new avenues for procurement process innovations, organizations can do more than just build resilience around their activities but also achieve competitive advantage in the market.

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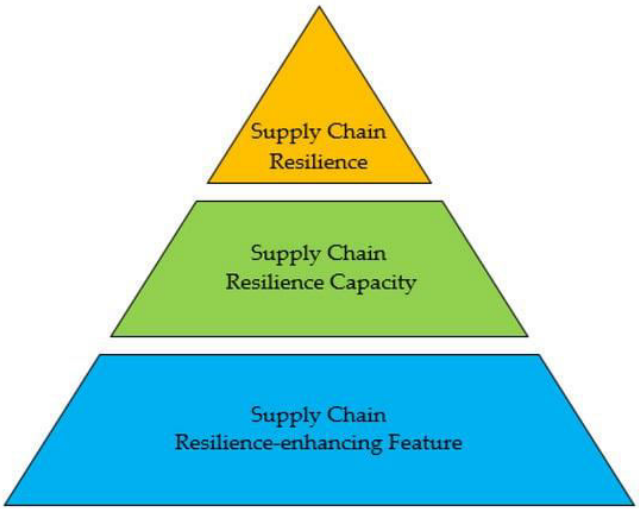

Figure 1: Layered view of Supply Chain resilience

Sustainability is another important dimension of resilient supply chains as in figure 1. Organizations are increasingly under pressure to address ESG concerns. Thus, integrating sustainability into procurement practices has become imperative. Sustainable procurement means procuring goods and services in ways that minimize environmental impact, promote social equity, and ensure ethical business practices. By aligning procurement strategies with sustainability goals, organizations can enhance their resilience to regulatory, reputational, and operational risks while contributing to broader societal and environmental objectives [5]. The paper explores the intersection of supply chain resilience, risk analysis techniques, and procurement innovation. It examines how advanced technologies and analytical frameworks can be leveraged to enhance risk identification, assessment, and mitigation, thereby fostering innovation in procurement practices. The discussion also focuses on the sustainability of building resilient supply chains, and the necessity for holistic and forward-looking approaches to risk management and procurement. This paper, therefore, reviews the existing literature and case studies in order to provide insights into best practices for building resilient supply chains that are not only robust and adaptive but also innovative and sustainable.

The following sections of the paper will delve into the theoretical underpinnings of supply chain resilience and risk analysis and explore emerging trends and technologies that are changing the face of procurement innovation. Practical strategies for enhancing supply chain resilience in the face of the modern challenges will also be provided. Addressing the critical nexus of resilience, risk, and innovation, this paper aims to contribute to the growing body of knowledge on supply chain management and generate actionable insights for practitioners and policymakers alike [6].

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2. Materials and Methods: A New Framework on Resilient Supply Chain and Procurement Risk Management

This section introduces the comprehensive and new framework regarding the study of resilient supply chain systems and procurement risk management strategies. This method puts together the sophisticated qualitative methods with the new digital methods and tools in an innovatively creative manner, yielding new insights on how resilience is built in response to evolving risks.

2.1 Research Approach

The mixed-method qualitative framework was adopted for collecting, analyzing, and validating data systematically. This helped in bridging the knowledge gap between traditional procurement risk management practices and contemporary digital advancements. The research explored a multi-dimensional perspective by combining semi-structured interviews, document analysis, and case studies to extract meaningful insights.

2.1.1 Participant Selection and Sampling

A purposive sampling strategy was employed to ensure that only those participants with extensive experience in supply chain and procurement management were selected. The sample included 25 professionals from different sectors such as manufacturing, retail, healthcare, and technology. The selection criteria ensured that participants had a minimum of five years of professional experience in procurement or supply chain management. This ensured that the insights captured represented credible and actionable practices [7].

2.2 Data Collection Techniques

2.2.1 Semi-Structured Interviews

The core data collection method involved conducting semi-structured interviews via video conferencing. A general interview guide enabled respondents to give their stories and experiences with flexibility without confining the researchers to some narrow questions while probing more sensitive areas. Interviews were conducted between January and June 2024 for between 45 and 90 minutes. The open-ended questions were intended to garner an understanding of the following aspects:

- Risk identification and risk mitigation techniques
- Strategies for supplier relationship management
- Adoption of digitalization in procurement risk management
- Policies to improve overall resilience in the supply chain

All interviews were audio recorded after taking participants' permission and later transcribed to conduct thematic analysis.

2.2.2 Document Analysis

Document analysis involved the use of organizational policies, industry reports, and academic publications to contextualize the findings. The papers selected were from the last five years to reflect the latest trend and practice in procurement and supply chain resilience [8].

3. Case Studies

Three in-depth case studies were constructed, representing diverse industries:

- A global electronics manufacturer adapting to geopolitical supply chain disruptions.
- A healthcare provider managing pandemic-induced procurement challenges.
- A retail giant leveraging digitalization to optimize risk management.

Case studies were developed using publicly available information and insights gathered from interviews, offering practical illustrations of resilience-building strategies.

3.1 Data Analysis

Thematic analysis was used to identify patterns that were repeated across the interview transcripts, documents, and case study findings. The coding process was iterative and consisted of three stages:

- Initial Coding: This involved generating codes based on key themes from the research objectives and literature review.
- Focused Coding: This was a refinement of the initial codes to group related themes.
- Theme Development: This involved consolidating codes into broader themes representing critical aspects of procurement risk management [9].

3.2 Triangulation

To ensure the generalizability and reliability of the results, data was triangulated from various sources. Triangulation between interview insights, contents of documents, and case study evidence ensured strong support to the conclusions.

3.2.1 Member Checking

The respondents participated in validating the results by engaging in member checking. Results and themes were given to respondents for their review. Any feedback obtained was integrated into the findings as part of refining the analysis.

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3.2.2 Ethical Considerations

Ethical protocols were strictly adhered to in the study. Informed consent was obtained, and participants were assured that their responses would be confidential and anonymous. Data were safely kept and used only for research purposes.

4. Technological Integration

This study involves the use of modern digital tools as part of the research methodology as in figure 2. The application of analytics and visualization software improved the analysis of complex data sets. Specific technological methods are:

4.1 Facilitated coding and thematic extraction of qualitative data.

Network Visualization Tools

Mapped the relationships between the suppliers and risks in terms of better understanding the vulnerability [10].

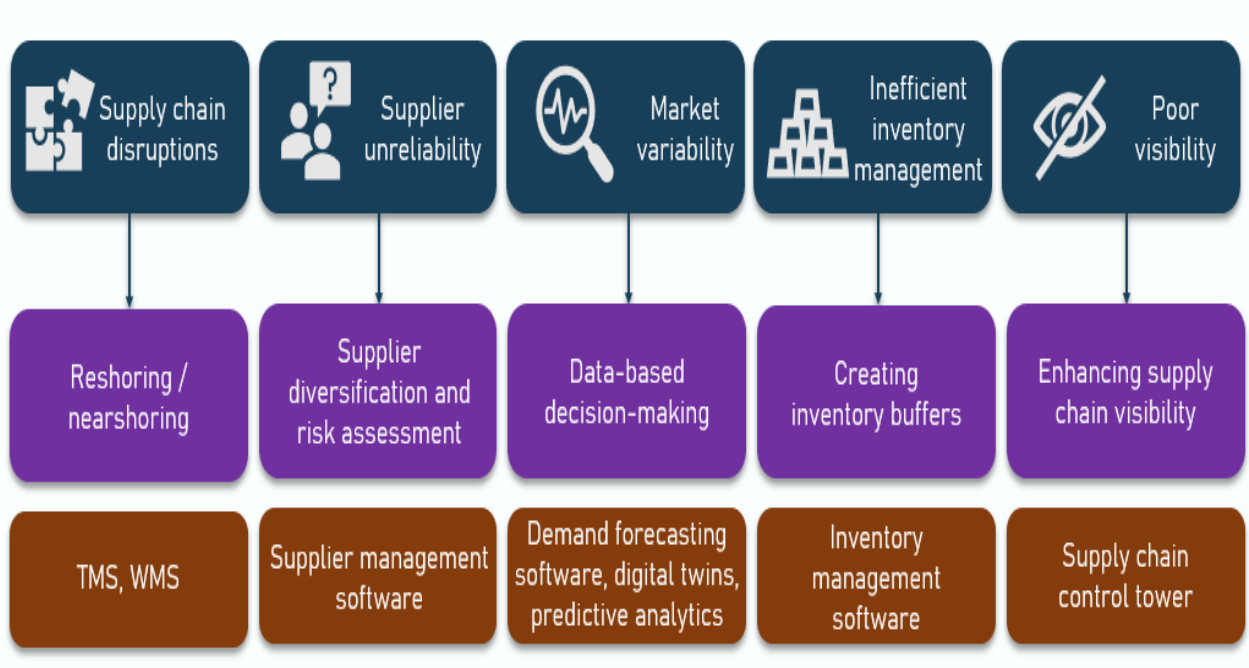

Figure 2: SCM Resilience strategies

4.1.1 Predictive Models

Probed into the pattern for procurement disruptions using the data from interviews and reports generated from industry sources as the inputs.

This method can be regarded as the modern future method of conducting research in analyzing the dynamic environment and its impacts on global markets due to its integration of classical approaches with digital tools.

4.1.2 Contributions of the Proposed Framework

The novelty of this framework lies in integrating qualitative insights, contextual analysis of documents, and application to real-life situations by using case studies. It also infuses digital tools within the analysis process to present a contemporary and scalable approach that deals with the nuances of modern supply chain environments. This integrated framework not only provides actionable strategies for practitioners but also contributes to the academic discourse about building resilient supply chains.

4.1.3 Toward Sustainable Supply Systems: Moving Beyond Boundaries

A. Expanding the Systems Perspective

To foster sustainability in supply chains, it is critical to expand the perspective beyond traditional economic considerations to encompass environmental and social dimensions. This integrative approach acknowledges the interconnectedness of systems and focuses on developing strategies that enable both adaptability and long-term resilience. The process begins with defining system boundaries effectively, balancing qualitative assessments and operational constraints.

B. Dynamic Feedback and Adaptive Learning

Supply chains inherently operate as dynamic systems influenced by both internal interactions and external pressures. As such, incorporating mechanisms that enable feedback loops and adaptive learning is essential for maintaining functionality amidst disturbances. This involves fostering collaboration among stakeholders and leveraging technological advancements to enhance monitoring, forecasting, and decision-making capabilities.

C. Resilience Through Multi-Layered Design

The resilience of supply systems is deeply rooted in their structural and operational configurations. To achieve this, supply chain designs should include:

- Robust Structural Elements: Redundant systems, buffers, and diversified supply sources.
- Operational Flexibility: The ability to reconfigure processes and redirect resources dynamically.
- Stakeholder Engagement: Active participation and shared responsibility among suppliers, manufacturers, and customers.

D. Sustainability as a Core Principle

Sustainable supply chains prioritize environmental and social objectives alongside economic goals. Key areas include:

- Emission Reduction: Minimizing carbon footprints through efficient logistics and alternative energy sources.
- Transparency and Ethics: Ensuring ethical sourcing and complete visibility throughout the supply chain.

- Circular Economy Practices: Emphasizing recycling, reuse, and waste reduction to create closed-loop systems.

E. Leveraging Technology for Sustainable Outcomes

Emerging technologies such as IoT, AI, and blockchain offer significant opportunities for transforming supply systems:

- IoT Integration: Real-time tracking and monitoring of material flows.
- AI-Driven Optimization: Predictive analytics for demand forecasting and risk management.
- Blockchain for Transparency: Secure and immutable data records to enhance trust and accountability.

4.2 Guiding Principles for Implementation

To operationalize sustainability and resilience, organizations should adhere to the following principles:

- Systems Thinking: Holistically evaluating the interdependencies within the supply chain.
- Proactive Risk Management: Identifying vulnerabilities and developing preemptive strategies.
- Continuous Improvement: Iteratively refining processes based on performance assessments.
- Stakeholder Inclusivity: Ensuring diverse voices contribute to decision-making processes.

4.2.1 Future Directions

The transition toward sustainable and resilient supply systems requires ongoing research and collaboration across disciplines. Future work should focus on:

- Developing quantifiable metrics for system boundaries and resilience.
- Exploring innovative business models that prioritize sustainability.
- Enhancing the scalability and accessibility of sustainable practices for global adoption.

By embedding these strategies, supply systems can evolve to meet the challenges of a rapidly changing world while contributing to a sustainable future.

5. Empirical Results

This part has two sections. Section 5.1 explains the approach adopted for tabulation of data, descriptive analysis of the survey, and its interpretations. Section 5.2 explores the PLS-SEM technique in detail. The interpretations of the PLS-SEM results, including both measurement model assessment and structural model assessment, are given within the same subsections.

5.1 Data Tabulation and Descriptive Statistics

The survey data was tabulated using MS Excel to allow ease, speed, and accuracy in feeding the responses from the instrument sections. For convenience, headings of responses were abbreviated to shorter terms. In order to use the data in PLS-SEM, the researcher saved the data

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in.csv format as recommended by the SmartPLS3 guidelines (J.F. Hair, Hult, Ringle, & Sarstedt, 2017).

The respondents in this study were from Indian plastics manufacturing organizations. As defined in the scope of the study, the sample encompassed organizations of all types involved in plastics manufacturing. A total of 150 questionnaires were distributed, out of which 137 were completely filled and included for analysis. Figures 3 to 8 present the descriptive statistics of the 137 respondents. Detailed information on the sample size and its rationale was discussed in the previous chapter. This section provides insights into the demographic and descriptive profiles of the respondents and their organizations.

A. Gender Distribution

Of 137 respondents, 130 were male, and 7 were female. Figure 3 highlights the lower involvement of female executives in supply chain management (SCM) and manufacturing-related functions within the Indian plastics industry.

B. Age Distribution

The study was conducted among different age groups, but the majority were between 30–40 years of age. Figure 4 represents the age variation of the respondents.

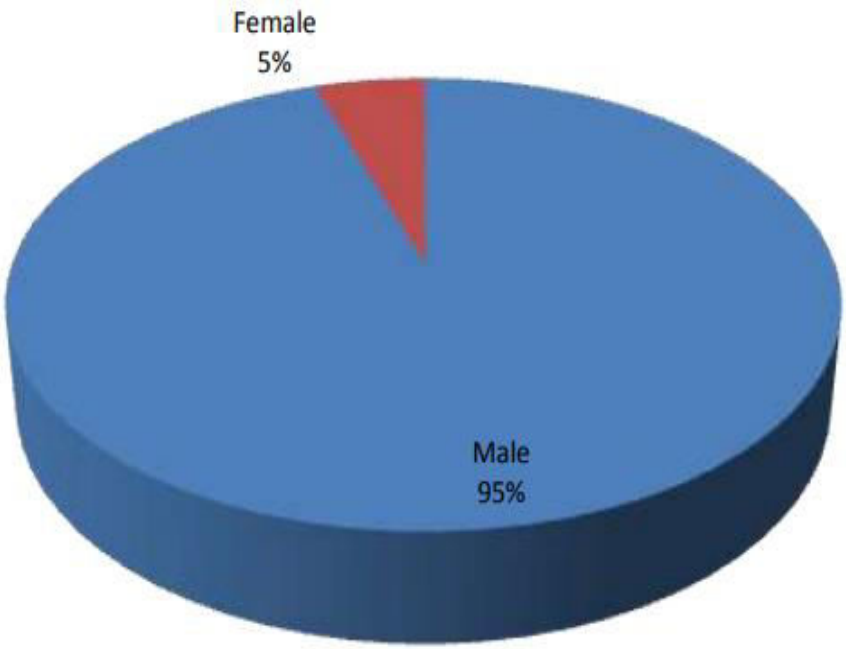

Figure 3: Gender-wise Distribution of Respondents

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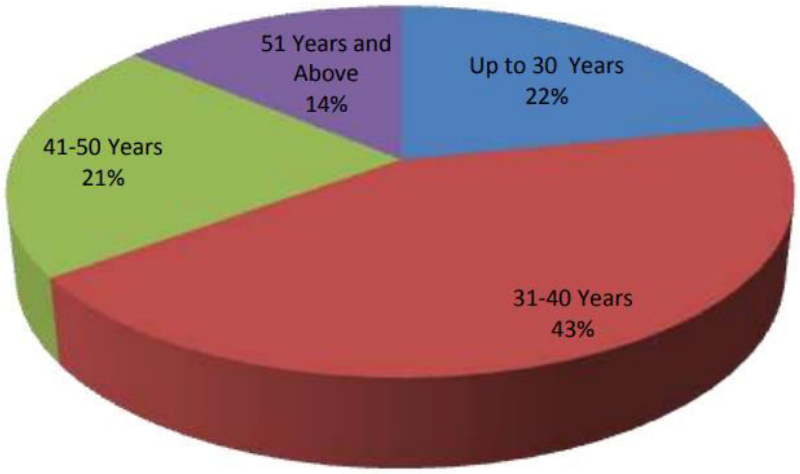

Figure 4: Age Distribution of Respondents

C. Departmental Representation

Respondents belonged to 41 different departments, which were further categorized into 15 groups based on commonality and nomenclature. Maximum number of respondents had been drawn from marketing/sales-related functions, followed very closely by production, manufacturing, and tool room departments.

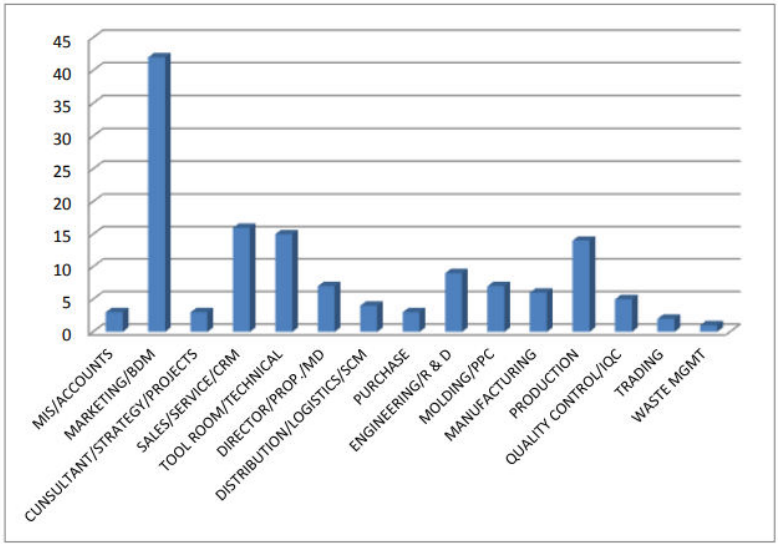

Figure 5: Department-wise Representation of Respondents

D. Years of Experience

The years of experience among the respondents varied between 1 and 30 years. The experience distribution is illustrated in Figure 5.

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E. Functional Area Representation

Majority of the respondents, 25%, belonged to manufacturing functions, followed by marketing (23%), sales (17%), research and design (12%), distribution (10%), purchase (7%), and MIS/IS areas. Figure 6 presents the functional area distribution among the respondents.

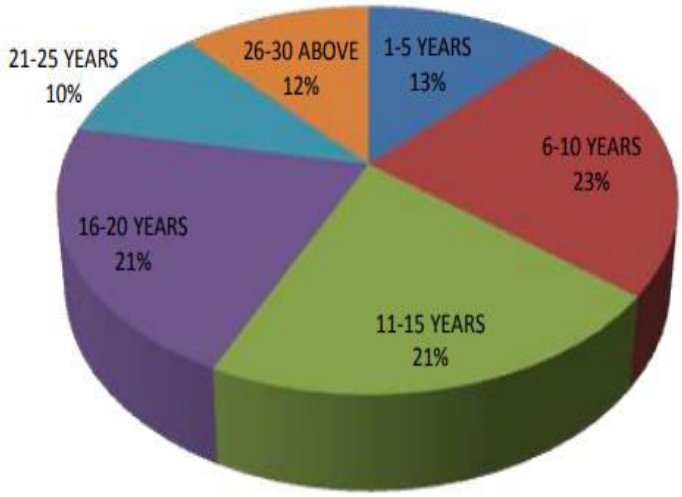

Figure 6: Experience Distribution in Years

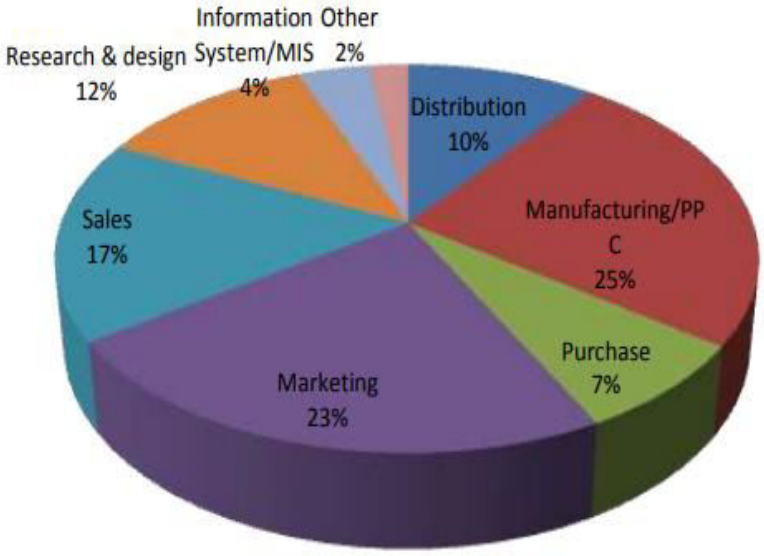

Figure 7: Respondents' Distribution by Functional Area

F. Organizational Profile

The following section of the demographic analysis looked at the type of organizations represented in the study. Respondents were from different businesses within the plastics industry, including machine and equipment manufacturers (highest representation), molding, raw material

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manufacturing, distribution, and printing [11] and packaging businesses. Several organizations conducted multiple types of business activities. For example, an organization was involved in molding and assembly operations as in figure 7 & 8.

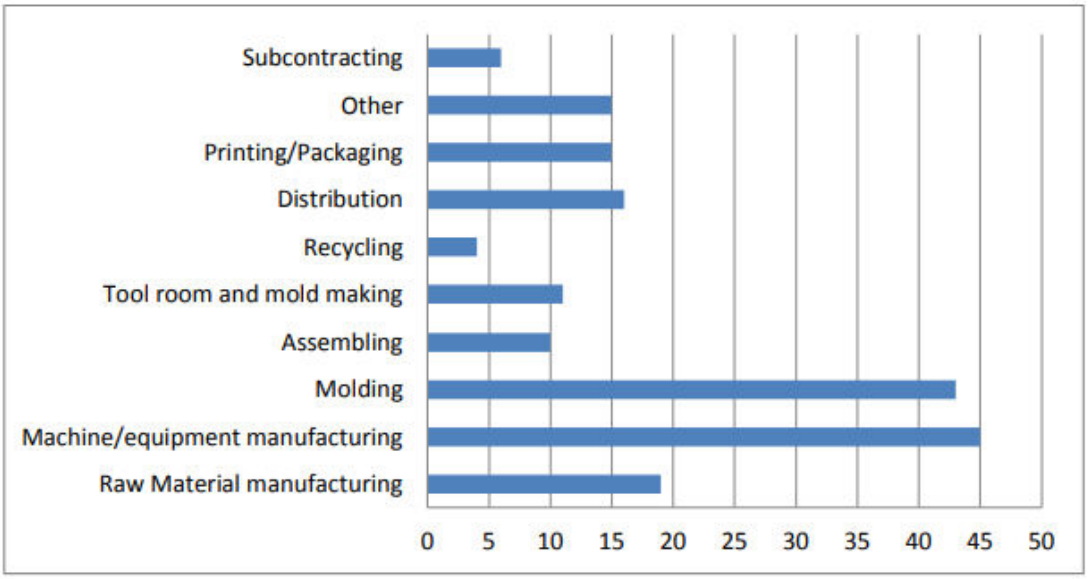

Figure 8: Organisational Distribution of Respondents

This analysis gives an elaborate demographic break-up ensuring that the study captured a diverse and representative sample of the Indian plastics manufacturing sector. Table 1 provides the discussion section in detail.

Table 1: Overall discussions

Key Area	Key Points	Details/Insights	Implications/Contributions
Resilience and Predictive Models	Focus on integrating predictive models and digital tools to enhance supply chain resilience.	Integration of classical approaches with modern digital tools, such as data analysis from industry sources.	Provides a contemporary and scalable approach to analyze global market disruptions and procurement issues.
Framework Contributions	Combines qualitative insights, contextual analysis, and real-life case studies to create actionable strategies.	Case studies and document analysis are integrated into a digital analysis process, offering practical solutions for real-world	Enhances academic discourse on building resilient supply chains, while offering actionable strategies for practitioners.

		supply chains.	
Sustainability in Supply Chains	Expands systems thinking to include environmental and social dimensions alongside economic factors.	Integrates environmental and social factors into traditional economic models for a holistic view of supply chain resilience and sustainability.	Encourages a broader, more integrative approach to supply chain design, considering the long-term environmental and social impacts.
Adaptive Learning & Feedback	Emphasizes the importance of feedback loops and adaptive learning for maintaining supply chain functionality amidst disruptions.	Systems in supply chains need to be dynamic and adaptable, able to respond to internal and external pressures for continuous functionality.	Fosters collaboration among stakeholders and incorporates adaptive learning for future disruptions, ensuring sustained supply chain resilience.
Design for Resilience	Resilience achieved through redundant systems, operational flexibility, and stakeholder engagement for a robust supply chain design.	Redundant systems, flexibility in operations, and strong stakeholder relationships create a robust system capable of withstanding and adapting to disruptions.	Results in a resilient supply chain capable of managing unexpected changes, ensuring ongoing operations and reducing the risk of failure.
Technology for Supply Chain Improvement	Leverages IoT for real-time tracking, AI for predictive analytics, and blockchain for transparency to improve supply chain processes.	Emerging technologies play a vital role in providing insights for demand forecasting, risk management, and transparent, secure operations in supply chains.	Enhances operational efficiency and transparency in supply chain processes, contributing to smarter decision-making and better stakeholder trust.
Implementation	Proposes systems	These principles	Provides guidelines for

Principles	thinking, proactive risk management, continuous improvement, and stakeholder inclusivity as operational principles for supply chain resilience and sustainability.	create a comprehensive approach to managing supply chain risks, promoting inclusivity and ongoing development.	practitioners to operationalize resilience and sustainability in their supply chain strategies, ensuring they can adapt to evolving challenges and opportunities.
Future Directions	Future work suggested includes quantifying resilience, exploring new business models, and scaling sustainable practices globally.	Focus on developing concrete metrics for resilience and exploring innovative business models that prioritize sustainability.	Encourages further research and collaboration, emphasizing the importance of scalability in global sustainable practices.
Survey Data Analysis	Study conducted with 137 respondents from Indian plastics manufacturing companies, capturing a diverse and representative sample.	Respondents come from various functions within the plastics industry, providing diverse insights into the industry's supply chain management.	Ensures the study represents a broad spectrum of the industry, adding validity to the analysis and conclusions regarding supply chain resilience and sustainability in the Indian plastics manufacturing sector.
Gender Distribution	Gender distribution shows predominantly male respondents (130 males, 7 females), indicating a gender imbalance in SCM and manufacturing roles.	Gender disparity is present, with fewer female executives in the supply chain management and manufacturing sectors within India.	Highlights the need for more inclusive practices and gender balance in decision-making roles within the supply chain management sector.
Age	Majority of	The age	Reflects a workforce that may

Distribution	respondents were between 30-40 years old, with a varied age distribution.	distribution suggests a relatively youthful workforce in the Indian plastics industry, likely contributing to adaptability and modern approaches in supply chain practices.	be more open to adopting new technologies and approaches for supply chain resilience and sustainability.
Departmental Representation	Respondents came from 41 departments, categorized into 15 groups, with most coming from marketing/sales, followed by production, manufacturing, and tool room.	This distribution shows the diversity of functional perspectives present in the survey, covering all aspects of supply chain management and manufacturing.	Offers a comprehensive view of the key areas of focus within the industry, ensuring that the study considers input from a variety of functional areas.
Experience and Functional Area	Majority of respondents have experience spanning 1-30 years, with significant representation from manufacturing, marketing, sales, and R&D functions.	Experience levels vary widely, ensuring that insights from both newer and more seasoned professionals were captured.	Provides a balanced understanding of both evolving and established practices in supply chain management.
Organizational Profile	Respondents from various businesses in the plastics industry, including machine and equipment manufacturing,	Multiple types of businesses were included, offering a holistic view of the diverse organizational structures within	Ensures the study is relevant across various sectors within the plastics industry, offering a broad perspective on the challenges and strategies for resilient and sustainable supply chains.

	molding, raw material production, distribution, and packaging.	the industry.	

6. Conclusion

This research presents deep insights into the establishment of sustainable and resilient supply chains in the integration of predictive models, qualitative analyses, and technology. The framework places value on the balance of using classical approaches and newer digital tools, giving way to both practitioners and scholars more actionable strategies for tackling these issues in modern supply chain environments. The research highlighted the need to expand the system perspective beyond traditional economic goals, incorporating environmental and social dimensions. Key principles emphasized as foundational for operationalizing resilience include systems thinking, proactive risk management, and stakeholder inclusivity. The research also underlined the transformative potential of emerging technologies like IoT, AI, and blockchain, which enable real-time monitoring, optimization, and transparency across supply chains. The demographic analysis of respondents in the Indian plastics manufacturing industry further enriches the study, offering a grounded understanding of challenges faced in diverse organizational contexts. These findings reveal critical gaps, such as the underrepresentation of female executives and limited adoption of sustainable practices, which organizations must address to create inclusive and forward-looking supply chains. Future work in this direction should focus on developing quantifiable resilience metrics, exploring new sustainable business models, and scaling best practices worldwide. The collaborative efforts among disciplines and industries will create supply systems that are better equipped to withstand disruptions as they create a sustainable future.

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