



Modeling enablers of agile and sustainable sourcing networks in a supply chain: A case of the plastic industry

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ABSTRACT

To compete in emerging markets, a supply chain must perform well. Agile and sustainable sourcing practices can improve supply chain performance; however, their impact needs an optimal evaluation. Although few research studies offer frameworks for integrating agile and sustainable principles, none offer links to implementing these practices in the sourcing networks of a supply chain. The present study seeks to bridge these gaps by developing a framework that identifies and configures the enabling elements for creating agile and sustainable sourcing networks. This study aims to provide an implementable causal model that the plastic industry's supply chain could adopt. In the first phase of the research process, fifteen enablers are identified through literature and validated by Delphi experts. In the second phase, interpretive structural modeling is applied to establish the hierarchical relationships among these enablers and categorize them based on their functionalities. The model is demonstrated based on the real-life case study of a firm manufacturing plastic pipes and fittings. The proposed model identifies the strategic, operational, and performance level enablers and intends to help the managers incorporate the agile and sustainable criteria in their sourcing practices. The findings of this study provide several contributions to the literature and implications for the plastic industry.

1. Introduction

"Sourcing decisions have had and will continue to have a major impact on corporate success" (Giunipero et al., 2019, p.1).

Sourcing is a major component of a supply chain, as purchasing raw materials and items accounts for more than 50% of a firm's running production costs (Han et al., 2023; Mohammed et al., 2018). In today's interconnected and dynamic business environment, companies face numerous challenges, including changing market needs (Oliveira-Dias et al., 2022), supply chain disruptions (Moosavi et al., 2022), regulatory pressures, and increasing customer expectations (Sim and Kim, 2021). Concerns regarding supply chain performance have been aggravated by the global political and economic instability that has elevated the supply network's vulnerability to actual hazards (Karunathilake, 2021; Ngoc et al., 2022). Thus, many supply chains are reinventing their sourcing strategies since conventional approaches to sourcing are no longer

sufficient to meet these challenges (Ardito et al., 2020; Centobelli et al., 2022). Companies are always looking for ways to improve their sourcing networks; hence, any new practices that could optimize business are much appreciated (Nandi et al., 2021). To address these challenges effectively, businesses must build their sourcing networks agile and sustainable.

Agile and sustainable sourcing networks bring several benefits to firms. Agility, on the one hand, enables faster response times to market changes, reduces stockouts, and promotes adaptability in the sourcing process (Christopher, 2000; Oliveira-Dias et al., 2022). It allows for the flexibility needed to pivot strategies, identify new opportunities, and address emerging challenges in real-time. By doing so, companies can stay ahead of the competition and better meet customer expectations (Han et al., 2023). On the other hand, sustainability initiatives minimize the environmental impact, promote social responsibility, and ensure long-term viability (Shekarian et al., 2022). Sustainable sourcing

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reduces the carbon footprint and other environmental impacts and helps companies navigate a regulatory landscape that is increasingly stringent about responsible sourcing (Rashidi et al., 2020). Moreover, sustainable sourcing can lead to cost reduction in the long run. By embracing energy-efficient and environmentally friendly practices, companies can lower operational costs, conserve resources, and ultimately improve their bottom line (Holloos et al., 2012). Sustainability is not just a trend but a strategy for long-term business viability (Akhtar et al., 2023). Thus, by integrating agility and sustainability into their sourcing strategies, companies can enhance brand reputation, satisfy environmentally conscious customers, and reduce supply chain risks associated with regulatory compliance and resource scarcity (Ciccullo et al., 2018; Jahromi et al., 2022). Ultimately, organizations with agile and sustainable sourcing networks are better equipped to manage supply chain disruptions, such as natural disasters, geopolitical events, or global pandemics (Kazancoglu et al., 2022; Reyes et al., 2021). By implementing agile and sustainable criteria, companies can quickly identify alternative suppliers, adjust production plans, and optimize inventory levels to meet changing customer needs (Yusuf et al., 2020). Businesses can build resilient and responsible supply chains, ensure performance, and contribute to a sustainable future.

Gey et al. (2020, p.15) rightly said, "Sustainability practices are direct sources of sustainable competitiveness, but their performance impacts are improved when facilitated through agile practices."

Furthermore, it is observed that plastics are replacing metals in almost every sector (Iyer and Gaval, 2013). They are made and utilized in enormous quantities worldwide, and it has become a significant subject to study. The amount of plastics produced and used worldwide every year has increased remarkably in a human lifetime. Its production has increased exponentially from 2 million tons in 1950 to over 390 million tons in 2021. The plastics market is expected to increase in the upcoming years, reaching a value of over 810 billion U.S. dollars by 2030, with a compound annual growth rate (CAGR) of 3.7 percent from 2022 to 2030 (Statista, 2022). Because of the wide range of chemical and mechanical characteristics that plastics exhibit, they have numerous applications in various domains, such as packaging, construction, automobiles, electronics, and agriculture (Simon, 2019). By far, the most plastic is used for packaging (44%), followed by construction (18%), automobiles (8%), electronics (7%), agriculture (4%), and others (Plastic Soup Foundation, 2023).

Although plastic items are cheaper than metals, they cause substantial environmental and social concerns (Rhein and Schmid, 2020). They are made of chemicals and resins that create pollution and are neither environment nor society-friendly. The decomposition of plastic products takes millions of years when they are discarded. According to estimates, only 60 % of used plastic items are recycled, while the rest are thrown and untreated (Khandelwal and Barua, 2020). With the increasing pressure on the industry and the rising demand for unique products, companies must adapt their sourcing strategies to adhere to environmental and societal regulations while maintaining economic benefits. Consequently, studying the agility and sustainability concerns of the plastic industry becomes relevant (Nara et al., 2021).

Reviewing the pertinent literature, we found no study integrating both the agile and sustainable criteria that cater to the upstream of a supply chain. i.e., sourcing networks. Also, we found no study that considers the plastic industry to model its sourcing practices. Therefore, based on these research gaps and needs, the present study focuses on the following research questions (RQs):

RQ1. What are the enablers responsible for agile and sustainable sourcing in the plastic industry?

RQ2. What are the specific enablers that play the role of strategic, operational, or performance level enablers?

To seek answers to the above research questions, the 'initiation approach' of mixed-method research proposed by Golicic and Davis

(2012) is adopted in this study. RQ1 is answered using a qualitative method, i.e., the Delphi technique. RQ2 is answered using a quantitative method, i.e., interpretive structural modeling (ISM). We base our findings on a real-life case of a firm manufacturing plastic pipes and fittings. The case study approach is suitable for understanding real-world processes, challenges, and events (Yin, 2009). This approach has the advantages of relevance and exploratory depth (Meredith, 1998). Thus, we have considered the case of a plastic firm as the plastic industry is growing tremendously because of its cost benefits; however, they are creating huge sustainability concerns (Hariram et al., 2020; Li et al., 2021).

Moreover, to understand the enablers of agile and sustainable sourcing, we have applied the theoretical lenses of contingency theory and extended resource-based view (ERBV). In contemporary business environments, the amalgamation of contingency theory and ERBV holds paramount significance when examining the enablers of agile and sustainable sourcing within firms (Li et al., 2023). An enabler refers to a factor, element, strategy, resource, or capability that facilitates the achievement of a specific outcome or an objective (Danese et al., 2019; Singh et al., 2021; Yeh et al., 2006). Contingency theory underscores the need for organizations to adapt their sourcing strategies according to external and internal factors (Grötsch et al., 2013). ERBV extends the focus beyond internal capabilities to encompass external resources, such as process integration, suppliers as partners, and global sourcing in the present context (Lewis et al., 2010; Yang et al., 2019). When leveraged effectively, these internal and external factors give firms a distinctive advantage in their sourcing practices. When firms can align their sourcing strategies with the specific contingencies they face, they are better equipped to navigate dynamic market conditions and reduce risk (Pavlov et al., 2019). Thus, by combining contingency theory and ERBV viewpoints, firms can identify and leverage the enablers responsible for achieving agility and sustainability in their sourcing practices.

Ultimately, the present study provides the following significant contributions to the literature and practitioners in the industry:

- It is one of the initial studies integrating agile and sustainable sourcing principles in a single framework.
- A conceptual model is proposed based on the enabler's functionalities (strategic, operational, and performance levels) and their interrelationships.
- The enablers are organized into four clusters according to their degree of driving and dependence powers toward agile and sustainable sourcing networks.
- The managers can formulate strategies targeting the specific set of enablers as per their functionality or driving/dependence powers.
- When these enablers are adequately handled, the service level of the complete sourcing network is improved, the quality of the products and services is enhanced, the cost is reduced substantially, and ultimately, the whole supply chain starts performing effectively.

The rest of the article is structured as follows: Section 2 provides the literature review pertinent to the study, segregated into four subsections, i.e., theoretical lenses, agile sourcing, sustainable sourcing, and research gaps. Section 3 presents the employed methodology addressing the study's research objectives in two phases, i.e., qualitative and quantitative. Section 4 demonstrates the methodology with the help of a real-life case study of a plastic firm. Section 5 discusses the results of the study. Implications of the study are provided in section 6. Finally, section 7 concludes the study by highlighting its limitations and scope for future research.

2. Literature review

As we are interested in exploring those enablers that make it possible to source in an agile and sustainable manner, this study is carried out through the theoretical lenses of the ERBV and contingency theory. Also,

the present study is related to the literature on two supply chain streams, i.e., agile sourcing and sustainable sourcing.

2.1. Theoretical lenses

The ERBV, an expansion of RBV, provides businesses with guidance on how to best put their resources and talents to maintain their competitive edge (Mathews, 2003; Yang et al., 2019). According to ERBV, an organization may tap into external value-creating resources in addition to those it already has inside its internal boundaries (Lavie, 2006). Collaboration across organizational boundaries is required for both agile and sustainable sourcing (Rashad and Nedelko, 2020). Being one of the firm's most valuable external resources, suppliers may be fostered and strengthened via agile and sustainable sourcing (Akhtar et al., 2023). In line with ERBV, we contend that the impact of agile and sustainable sourcing on supply chain performance is primarily attributable to resource benefits derived from these sourcing strategies. Therefore, ERBV is an appropriate lens for this investigation.

In addition, the contingency theory stresses the need for an ideal alignment between an organization's strategy and its business environment (Grötsch et al., 2013). There is growing evidence that the relationship between agile and sustainable sourcing is influenced by various environmental factors (Mathiyazhagan et al., 2021; Sahu et al., 2023). According to contingency theory, strategies must be flexible and long-lasting to adapt to changing circumstances and remain effective. Agile and sustainable firms will fare better in the face of uncertainty if they see it through the lens of contingency theory (Carter and Rogers, 2008). As a result, organizations may make the 'fit' between their resources and the external environment more 'contingent' (Romero-Silva et al., 2018). Consequently, we analyze the present study using the theoretical lenses of ERBV and contingency theory.

2.2. Agile sourcing

Agile sourcing practices are developed and implemented to enhance supply chain performance and increase organizational effectiveness. Agile sourcing is a procurement method that enables organizations to quickly adapt to changing business requirements and market conditions (Nicoletti, 2018). This flexible approach allows supply chain partners to utilize their capabilities and establish appropriate connections to improve supply chain performance (Modgil et al., 2022). Compared to conventional sourcing practices, agile sourcing has the potential to provide shorter lead times, collaborative relationships, and greater customer satisfaction (Guo et al., 2016). Adopting agile sourcing has far-reaching implications for strategic sourcing, providing significant advantages in supply chain management. With the advent of agile sourcing, suppliers are transformed into strategic partners responsible for the entire product lifecycle (Drake et al., 2013). The customer-supplier dynamic shifts, opening the door for outcome-based collaborations and new approaches to strategic collaboration (Rashad and Nedelko, 2020). The rise of agile sourcing highlights the importance of building relationships with suppliers, shifting accountability upstream in the supply chain, and involving employees in the process (Han et al., 2023). Agile sourcing acknowledges that an agile supply network cannot be achieved solely through the responsiveness of a solitary supplier; instead, it requires the ability of the buyer organization to coordinate and streamline the entire supply chain. This involves economic restructuring to optimize the network's performance (Purvis et al., 2014). Consequently, when businesses adopt agile processes, the focus shifts from buying and contracting to managing a network of key suppliers (Sahu et al., 2023).

The shift towards agile sourcing by procurement departments is imperative in today's highly competitive business environment (Shukor et al., 2021). Companies respond to changing customer requirements, market trends, and other factors to maintain a competitive edge (Hu et al., 2022). Based on the research conducted by Kim and Chai (2017), the application of agile sourcing requires a greater reliance on a broad

range of suppliers and the ability to swiftly and easily adjust the supply chain. Firms operating in unstable environments may benefit from having multiple supply bases as this provides diversity and enhanced organizational flexibility, as Masson et al. (2007) posited. As a result, the level of agility obtained after a network reconfiguration is contingent upon the leading firm's capability to coordinate and integrate the entire team (Rout et al., 2021).

2.3. Sustainable sourcing

Incorporating sustainability criteria into a company's sourcing strategy has become more critical in recent years (Akhtar et al., 2023; Digalwar et al., 2020). Sustainable sourcing refers to achieving environmental, social, and economic sustainability, i.e., the triple bottom line (TBL), in a company's sourcing activities (Alhaddi, 2015; Gimenez et al., 2012). Companies are only as good as their upstream suppliers (Ding et al., 2005), and they need to choose sustainable suppliers to avoid being held responsible for their suppliers' unsustainable actions (Rao, 2002). They adopt various approaches to manage their suppliers to achieve sustainable objectives. They use formal evaluation systems and external requirements to gauge suppliers' sustainability performance as part of their monitoring efforts (Luzzini et al., 2014). Similarly, they may pressurize their suppliers to comply with environmental regulations such as ISO 14001 to avoid noncompliance costs and reputational damage (Akhavan and Beckmann, 2017). By adopting sustainable sourcing practices, companies can reap positive effects on supply chain performance, including improved supply reliability and up-to-date data (Rashidi et al., 2020).

There are two ways in which sustainable sourcing can improve supply chain performance. First, sustainable sourcing enhances suppliers' capabilities (Paulraj, 2011). An organization's ability to rely on its suppliers and the overall performance of its supply chain is improved when suppliers can better meet the organization's needs and prevent issues like price fluctuations, supply shortages, and poor quality (Li et al., 2017). Second, sustainable sourcing allows businesses to work with their suppliers on a solid foundation (Zhu et al., 2012). By developing such a strong bond, both suppliers and purchasing companies increase the likelihood that their goals and interests will coincide (Kim and Chai, 2017). Purchasing organizations include their suppliers in their long-term strategies because they see their vendors as crucial partners in achieving their goals (Paulraj, 2011). Therefore, suppliers adopt practices in response to requests from their client companies (González-Benito et al., 2016). Companies with similar goals are more likely to work together to address changes in the business environment, which benefits the purchasing company's supply chain performance (Mofokeng and Chinomona, 2019). Companies' collaborative relationships with their suppliers provide improved communication, allowing for rapidly disseminating market demand shifts to suppliers (Hollos et al., 2012). Suppliers may better know the purchasing company and its shifting supply demands if the two parties regularly and effectively communicate. Accordingly, the buyer firm will be better able to adapt its offerings in response to changing market needs and consumer preferences (Kahn et al., 2006).

2.4. Research gaps

Numerous studies exist that are performed in the context of agile (see, e.g., Baramichai et al., 2007; Korucuk et al., 2023) or sustainable sourcing in a supply chain (see, e.g., Akhavan and Beckmann, 2017; Carter and Rogers, 2008). Scholars in the field have also made efforts to link the phenomena of agility and sustainability in various contexts. For instance, Soundararajan et al. (2021) proposed a procedural framework combining top-down and bottom-up governance approaches to create agile-sustainability governance (ASG) mechanisms. By analyzing supplier challenges and identifying enabling resources and relational dynamics, they demonstrated the importance of ASG mechanisms in coordinating the supply chains in emerging markets. The study by Kazancoglu et al. (2022)

highlighted the significance of agility and responsiveness in minimizing the disruptions caused by pandemics such as COVID-19. The research centered on the resilience of sustainable global supply chains and their response to pandemics, utilizing the dynamic capability perspective and contingency theory to develop theoretical models for COVID-19. Considering the substantial demand and time constraints, [Yadav and Kumar \(2022\)](#) emphasized the necessity of a more resilient and organized distribution network for pandemic/outbreak vaccination. They advocated for implementing lean-agile-green practices to enhance the efficiency of the vaccine supply chain regarding operational, economic, and environmental performance. In the study by [Jahromi et al. \(2022\)](#), the pharmaceutical supply chain network was analyzed to achieve both agility and sustainability benefits. A digraph was utilized to represent the feasible structure of the supply chain, and the goal programming approach was employed to achieve an optimum configuration. Similarly, the article by [Khandelwal and Barua \(2020\)](#) presented a perspective on implementing circular supply chain management (CSCM) in the plastic industry. CSCM integrates the principles of circular economy into supply chain management and offers a new approach to sustainability. Their study aimed to investigate and prioritize CSCM barriers in the plastic industry in emerging economies. Nevertheless, with the comprehensive literature study, we identified the following research gaps (RGs) existing in the literature that need to be addressed:

RG1. None of the studies has outlined the enablers leading to agile and sustainable sourcing networks in the context of the plastic industry.

RG2. The causal relationships (contextual relationships) among these enablers are not defined, and the levels at which they function to achieve supply chain performance are unclear.

Therefore, this study attempts to close these gaps by identifying the enablers leading to agile and sustainable sourcing networks and their roles in the plastic industry. Performing this study by employing qualitative and quantitative research approaches with the help of an actual case will add to the existing body of knowledge. It will enhance literature by providing a reference point for the scholars and practitioners in the field.

3. Research methodology

This research aims to configure the enablers responsible for agile and sustainable sourcing in the plastic industry. Thus, the present study fulfills the following research objectives (ROs):

RO1. To determine the enablers for agile and sustainable sourcing in the plastic industry.

RO2. To establish the contextual relationships among the enablers.

RO3. To propose a causal model comprising the functionality level of enablers, i.e., strategic, operational, and performance level enablers.

RO4. To categorize the enablers in terms of their driving and dependence powers.

To achieve the above-mentioned research objectives, the 'initiation approach' of mixed method research proposed by [Golobic and Davis \(2012\)](#) is adopted in the present study. The idea to use the mixed method research design for this study's subject is also supported by the argument made by

the authors, i.e., "sustainability, a salient phenomenon in current supply chain research, is another example of a fertile area that could benefit from a mixed method approach" ([Golobic and Davis, 2012](#), p.15). The initiation approach is implemented when there is a need to conduct a preliminary investigation of the phenomenon to identify essential variables or establish interrelations among them. The findings of the initial research method are utilized as the basis for the second method employed in the study. Thus, in this study, RO1 and RO2 are achieved through a qualitative method. The results of the qualitative method are incorporated as the input for RO3 and RO4, which are addressed using a quantitative method.

Many research studies in the past have successfully utilized the initiation approach of mixed method research. For instance, [Lyons et al. \(2020\)](#) employed this approach to investigate the impact of increased product variety on a range of business processes within and across supply chains. [Thomas et al. \(2014\)](#) utilized the approach to examine the causes of time pressure in retail supply chain relationships. Similarly, [Yang et al. \(2023\)](#) used this approach to link relation-specific investments and supply chain performance, determining the role of supply chain learning in this regard. Such a mixed method research design is found effective as it combines the qualitative and quantitative approaches in a single research project that generates multiple perspectives and assures the trustworthiness of the findings.

Hence, the present research work is carried out in two phases: (I) In the first phase, the Delphi technique is applied to determine enablers leading to agile and sustainable sourcing. The contextual relationships among the identified enablers are established with the help of expert opinion. (II) In the second phase, ISM is employed to design the hierarchical levels of the enablers and classify them into strategic, operational, and performance level enablers. Further, MICMAC analysis is performed, which clusters them into four groups, i.e., autonomous, dependent, linkage, and driver enablers. The detailed methodological framework implemented for this study is depicted in [Fig. 1](#).

3.1. Phase I: Qualitative analysis

3.1.1. Delphi technique

The Delphi technique is structured to facilitate focused discussions on complex problems, intending to achieve a group consensus through a series of iterations ([Powell, 2003](#)). It is a methodical and recursive process for verifying attributes such as enablers, critical success factors, obstacles, or criteria ([Dalkey, 2018](#); [Woudenberg, 1991](#)). Delphi's primary benefit is allowing each expert to contribute equally, reducing biases caused by influential personalities, competing viewpoints, and group pressure ([Hasson et al., 2000](#)). It is essential to ensure the participation of prospective panel members in multiple rounds of interviews and feedback to arrive at a consensus. [Balasubramanian and Agarwal \(2012\)](#) state that five to twenty experts are consulted throughout a Delphi process. In this study, we employed the Delphi technique to identify the pertinent enablers of agile and sustainable sourcing and to establish the contextual relationships among them.

Delphi employs numerous methods to assess expert agreement to validate attributes ([GrachtVon Der, 2012](#)). One of the robust methods, known as content validity ratio (CVR), is widely used among researchers. CVR and its scale were initially developed by [Lawshé \(1975\)](#), and its threshold values were revised and recalculated by [Wilson et al. \(2012\)](#). The CVR uses a balanced three-point scale with three options: essential, useful but not essential, and not necessary. The CVR is expressed as:

$$CVR = \frac{N_{PE} - \left(\frac{N}{2}\right)}{\frac{N}{2}} \left\{ \begin{array}{l} N_{PE} = \text{Number of experts expressing the enabler is essential} \\ N = \text{Total number of Experts} \end{array} \right. \quad (1)$$

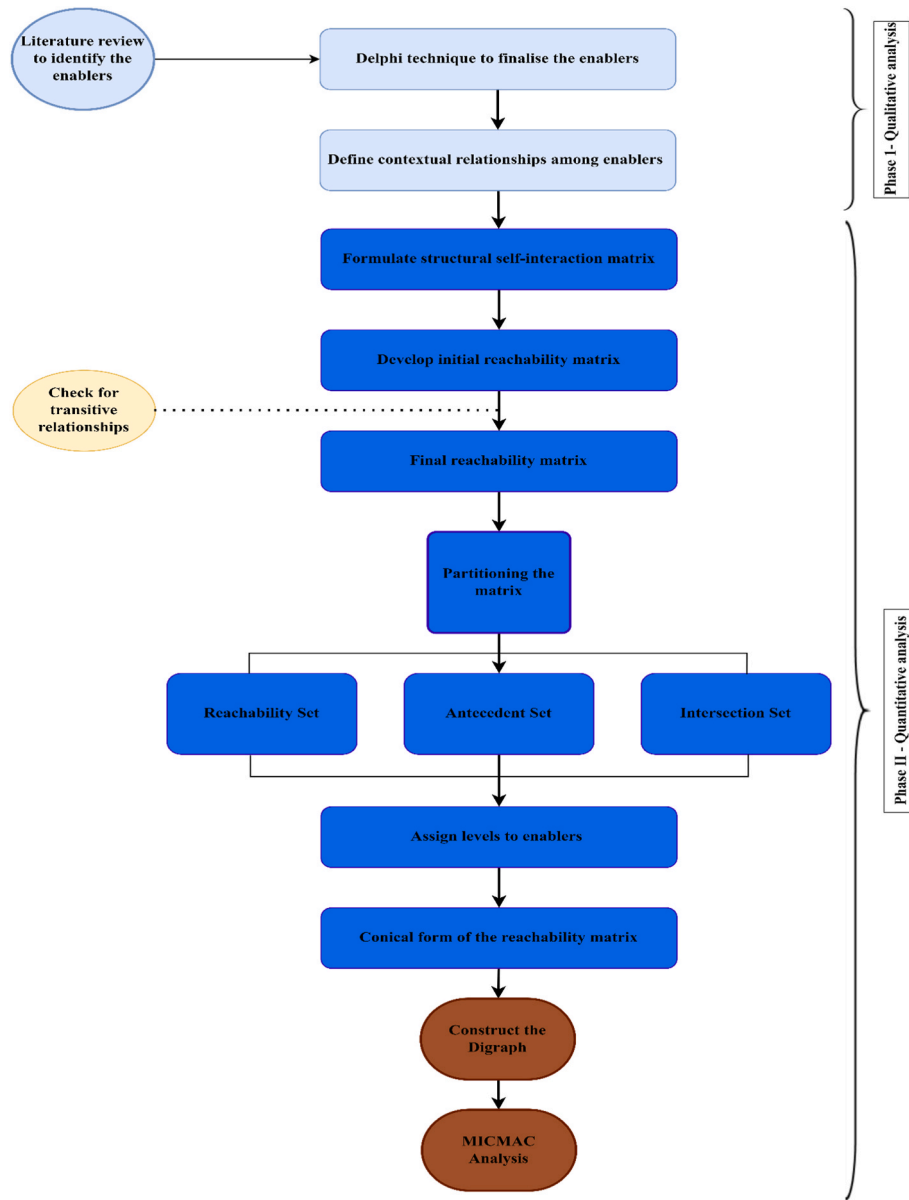


Fig. 1. Methodological framework.

CVR values of the items can range between +1 (perfect agreement) and -1 (perfect disagreement). The CVR threshold is decided based on the number of experts chosen for the study. The CVR threshold is generally set at 0.29 for the opinion gathered from the experts ranging between five and twenty (e.g., Emovon et al., 2018; Ghuge et al., 2022; Kim et al., 2013). Thus, the item with a CVR score ≥ 0.29 will be accepted, and the item with a CVR score < 0.29 will be rejected.

3.2. Phase II: Quantitative analysis

3.2.1. Interpretive structural modeling

Interpretive structural modeling (ISM) is employed in this study to better understand how various enablers interact. ISM employs a systematic approach to manage the chaos that might arise from the interdependencies between system components (Sarabi et al., 2020). The main goal of ISM is to facilitate collective learning. Since group brainstorming determines whether and how the enablers are connected, this approach is seen as interpretative. It has a structural quality as it uses

relationships to determine how to best organize a potentially chaotic collection of inputs (Malone, 1975). Similarly, it is a modeling strategy as a Digraph model represents the relevant links and the overall structure. Researchers attempt to organize diverse factors through ISM into a holistic model (Farris and Sage, 1975; Liu et al., 2020). The resulting model is a carefully crafted pattern, with the implications of visuals and words, that depicts the structure of a complicated issue or problem, a system, or a topic of study. As a modeling strategy, it works well for examining how one variable affects others (Agrawal, 2019). Thus, this solution offers a holistic method for agile and sustainable sourcing.

The ISM involves the following steps as depicted through the research framework of this study (Fig. 1):

Step 1: After determining the enablers, contextual relationships are established amongst them, assigning the symbols V, A, X, and O by adopting the following relationship rules between two enablers (suppose x and y):

- (i) If x leads to y, it is assigned the symbol V.
- (ii) If y leads to x, it is assigned the symbol A.
- (iii) If both x and y can lead to each other, the symbol X is assigned.

(iv) If no relationship exists between x and y , i.e., none leads to another, the symbol O is assigned.

Step 2: These relationships are then formulated into a structural self-interaction matrix (SSIM).

Step 3: The next step is to transform SSIM into an initial reachability matrix (having values 1 and 0), following the given rules:

- (i) V transforms to 1 for (x, y) entry and 0 for (y, x) entry.
- (ii) A transforms to 0 for (x, y) entry and 1 for (y, x) entry.
- (iii) X transforms to 1 for (x, y) entry and 1 for (y, x) entry.
- (iv) O transforms to 0 for (x, y) entry and 0 for (y, x) entry.

Step 4: Transitivity relationships are checked (if any), and the final reachability matrix (FRM) is created.

Step 5: The obtained FRM is partitioned into reachability, antecedent, and intersection sets.

Step 6: Based on these sets, levels are assigned to the enablers.

Step 7: A conical form of the reachability matrix is developed based on the levels of enablers in which they are positioned.

Step 8: A Digraph is constructed depicting the enablers' levels and the positional association reached among them.

Step 9: MICMAC analysis is then performed to check for the dependence and driving powers of the enablers.

Step 10: Finally, the MICMAC graph is developed in which the enablers are clustered into four groups: autonomous, dependent, linkage, and driver enablers.

The methodology proposed in Phases I and II has been utilized in the case of a plastic firm that manufactures plastic pipes and fittings, as outlined in the subsequent section.

4. Case study

This case study considers a firm belonging to the plastic industry, termed as a 'Case firm' here for confidentiality reasons. The Case firm currently incorporates over 800 employees and has evolved as India's third-largest manufacturer of plastic pipes and fittings. The plastic pipes are manufactured through the extrusion process, while plastic fittings (elbow, coupler, reducer, etc.) are manufactured through the injection molding process. To manufacture pipes and fittings, the firm purchases Polyvinyl chloride (PVC), High-density polyethylene (HDPE), and Polypropylene (PP) as raw materials. The firm offers a wide range of products of different dimensions and sizes, catering to diverse sectors such as agriculture, plumbing, borewells, and sewage. In the upstream, the firm's suppliers are mold and die makers, machine suppliers, raw material suppliers, and master batch providers (for adding special features like colors or scratch-free substances to the raw material). The firm sources raw materials from companies based in China and Germany.

With such an extensive sourcing and distribution network, managing the sourcing and procurement processes is a significant challenge to the firm. To combat this challenge, the firm has established long-term partnerships with key suppliers to ensure a stable supply chain. These partnerships foster mutual trust and enable proactive planning for raw material procurement. The firm has implemented waste reduction measures by adopting manufacturing standards that optimize material usage and minimize scrap generation. Likewise, the firm has a recycling department that recycles manufacturing wastes and utilizes them as input. It also conducts training programs for its employees regularly, encouraging them to adopt agile and sustainable practices in the plant.

As a plastic manufacturer, the managers of the Case firm are aware of the sustainability concerns related to plastic waste and pollution. Consumers and regulators have a growing demand for sustainable and eco-friendly products. Thus, managers are devoted to practices that will earn a positive reputation among environmentally conscious customers. Additionally, the firm must ensure the timely availability of raw materials, avoiding stockouts or overstocking. The demand for piping solutions is subject to market fluctuations and seasonal variations, requiring the firm to remain flexible in its sourcing strategies. By embracing agile

and sustainable sourcing practices, the managers of the Case firm want to set an example for the industry, showcasing how responsible sourcing practices can lead to business success and positively contribute to the world's efforts toward combating plastic waste and pollution. Following these requirements of the firm, this research work is an attempt to propose a model that will help achieve the Case firm's objectives. The research methods implemented with respect to the case are detailed below:

4.1. Implementing the Delphi

In the present study, ten experts were approached to participate in the Delphi sessions, and their availability was sought. Seven experts confirmed to participate in the expert opinion (five from the plastic industry and two from academia having subject matter expertise). The experts were chosen based on 1) the designation, 2) total years of experience, 3) an adequate understanding of the enablers, and 4) the willingness to assist (Bokrantz et al., 2017). Professionals with more than ten years of experience in the field were consulted. Table 1 represents the profile of the experts sought for the Delphi sessions.

During the first round, all participating panel experts were informed of this research's objectives, detailing to them the identified enablers of agile and sustainable sourcing. The panelists from academia were also updated about the plastic industry through available company reports, current industry trends, and relevant discussions. The discussion points were captured through notes, ensuring the required opinions and feedback. The opinions shared by the panelists were converted into meaningful information for our research. The initial literature search yielded sixteen enablers, which were discussed and refined in the first round. The panelists suggested a new set of enablers in addition to confirming the initially identified ones. Three new enablers (visibility, HR practices, and global sourcing) were suggested. Table 2 summarizes all the nineteen enablers identified in the first round.

The nineteen enablers identified from the literature and the panel experts in the first round were carried forward to the second round. In the second round, we requested the experts to rate the enablers' importance on a three-point scale: essential, useful but not essential, and not necessary. The CVR score of each enabler was calculated following Equation (1). Enablers with a CVR of at least 0.29 were finally selected, as explained in section 3.1. Based on the round 2 responses, enablers that obtained CVR greater than 0.29 were retained, and others were rejected. Four enablers (Best use of management tools, collaboration, HR practices, and delivery) were rejected. Most experts believed that 'Best use of management tools' and 'HR practices' were irrelevant in the present context. Additionally, it was found that 'suppliers as partners' and 'collaboration' were similar in nature, so experts suggested including the one more technically accepted in the industry. Similarly, it was found from the literature and discussions with the experts that 'lead time' also encompasses the characteristics of 'delivery.' Lead time pertains to the overall process and duration between receiving the order and successfully delivering it to the customer, while delivery simply refers to transferring goods or services to the customer. So, the experts' rating revealed that including the lead time rather than delivery was comprehensive, avoiding duplication in the present context. Table 3 summarizes all the enablers based on their CVR scores. Finally, a total of fifteen enablers were retained for further analysis.

In the third round of Delphi, we approached the same experts with the final list of enablers responsible for agile and sustainable sourcing in the plastic industry. They were asked to define the contextual relationships within the pairs of these enablers. Two authors transformed the obtained contextual relationships into symbols (V , A , X , O), as explained in section 3.2. In our case, the total number of paired comparisons was 105 (=15C2). We considered that relationship within a pair that got the majority consensus. The constructed matrix (SSIM) was utilized as the input for the ISM method, as demonstrated in the next section.

Table 1
Experts' profile.

Expert	Background	Designation	Company size	Educational Qualification	Experience (Years)
Expert-1	Industry	Procurement Manager	≈800 employees	Post-Graduate	12+
Expert-2	Industry	Manager – Operations	≈1600 employees	Graduate	14+
Expert-3	Industry	Supply Chain Analyst	≈900 employees	Post-Graduate	13+
Expert-4	Industry	Materials Manager	≈500 employees	Graduate	17+
Expert-5	Industry	Logistics Head	≈500 employees	Post-Graduate	11+
Expert-6	Academia	Professor-Operations Management	–	Ph.D.	23+
Expert-7	Academia	Professor-Logistics & Supply Chain Management	–	Ph.D.	21+

4.2. Implementing the ISM

ISM is implemented in the present case as a quantitative method to derive the hierarchical relationships among the enablers. The detailed implementation of ISM is discussed as follows:

4.2.1. Structural self-interaction matrix (SSIM)

Risk hedging (1), Innovation (2), Visibility (3), Resource Utilization (4), Process integration (5), Technological capability (6), Suppliers as partners (7), Government regulations (8), Cost reduction (9), Service level (10), Lead time (11), Quality (12), Flexibility (13), Knowledge management (14), and Global outsourcing (15), were found the essential enablers in making the sourcing agile and sustainable.

After the final round of Delphi, we obtained SSIM containing the contextual relationships among the enablers. The presence of a relationship between any two enablers, x , and y , and the direction of the association were taken care of while formulating the SSIM. Four symbols (V, A, X, O) were assigned in the SSIM, representing the different kinds of relations between the two enablers. For instance, enabler 1 leads to enabler 12 and is thus assigned V. Enablers 13 and 14 lead to enabler 1; thus, A is assigned to the cells of their intersection. Both enablers 1 and 15 can lead to each other; thus, X is assigned. Similarly, O is assigned at enablers 1 and 11 intersection as none leads to each other. Accordingly, all the relationships were transformed to formulate SSIM (Table 4).

4.2.2. Initial reachability matrix (IRM)

Now, each SSIM cell entry is transformed into a binary digit, i.e., 0 or 1, following the rules given in section 3.2. Thus, IRM is obtained as represented by Table 5.

4.2.3. Final reachability matrix (FRM)

Transitive relationships are checked among all the enablers in this step. Transitivity states that if an element 'A' leads to 'B' and 'B' leads to 'C,' then 'A' will lead to 'C' having a transitive relationship. For instance, enabler 1 does not lead to enabler 5; we have marked their cell as '0' in the IRM (Table 5). However, if we check for the transitivity, we find that enabler 1 leads to enabler 15 and enabler 15 leads to enabler 5, so enabler 1 will lead to enabler 5, showing a relationship. This transitive relationship between enabler 1 and enabler 5 is represented by '1*' in the updated matrix. Similarly, we can observe that enabler 1 leads to enabler 15 and enabler 15 leads to enabler 7, so enabler 1 will lead to enabler 7 having a transitive relationship. In this way, all the possible transivities in the matrix are checked; the relationships where the transivities occur are replaced from '0' to '1*', showing the relationship between those enablers. Thus, after this step, FRM is obtained (Table 6).

4.2.4. Partitioning the reachability matrix

The FRM is then partitioned into a reachability, antecedent, and intersection set for each enabler (Sarabi et al., 2020). The reachability set includes the enabler and the other enablers, which this enabler leads to achieve. In contrast, the antecedent set consists of the enabler and other enablers that help achieve it. The intersection set contains common elements from the reachability and antecedent sets. Further, if the reachability set and the intersection set are the same for an enabler, that

enabler is assigned the top-level enabler, i.e., level I. Since the top-level enablers in the ISM hierarchy would not contribute to achieving any other lower level enablers, they are removed from the set in further iteration. The next iteration is performed to obtain next-level enablers and removed accordingly from the set; thus, various iterations are performed until all the enablers are exhausted and assigned their levels. In our case, assigning the level to each enabler took nine iterations. Table 7 represents all the enablers' assigned levels in a consolidated matrix form.

We can see that enabler 9 is assigned level I. This enabler will be at the top of the Digraph. Enabler 12 is in the second position (level II), and enabler 10 lies in the third position (level III). Enablers 2, 11, 13, and 15 are positioned at level IV. Level V is matched with enabler 1. Level VI comprises enablers 3, 4, and 14. Level VII is assigned to enabler 8. Enablers 5 and 7 are next in the sequence and assigned level VIII. At last, the most bottom level is assigned to enabler 6 (level IX) in the ISM hierarchy.

4.2.5. Conical form of reachability matrix

The conical form of the reachability matrix is constructed by positioning the enablers across the row and column headers as per the sequence of levels assigned to them. The relationships among the enablers are extracted from the FRM to frame the conical matrix (Table 8).

4.2.6. Digraph

The initial Digraph (directed graph) was constructed based on the levels and relationships within the enablers as represented through the conical matrix. The final Digraph was obtained after removing the transitive links (Fig. 2). It is clear from the Digraph that the underlying tenets of sourcing networks, i.e., technological capability (TC), process integration (PI), suppliers as partners (SP), and government regulations (GR), are positioned at the base of the model and become most crucial in driving other enablers to achieve agility and sustainability. Thus, they play the role of 'strategic level' enablers in the hierarchy. Visibility (VI), resource utilization (RU), and knowledge management (KM) help mitigate risk across sourcing networks, and thus, risk hedging (RH) is achieved across the whole supply chain. The achieved RH then becomes the push for innovation (IN), flexibility (FL), and global sourcing (GS) strategies. Also, the product's lead time (LT) is reduced when the sourcing networks are visible and flexible enough. Therefore, VI, RU, KM, RH, IN, LT, FL, and GS together play the role of 'operational level' enablers in a firm. These enablers then improve the service level (SL) and quality (QU) and help in achieving cost reduction (CR) across the sourcing networks. Thus, SL, QU, and CR appear at the top of the developed model. Ultimately, they enable the performance of the sourcing networks and are thus treated as 'performance level' enablers in the hierarchy. The developed Digraph (Fig. 2) is constructed concisely to represent the inter-relationships among all the enablers and their levels in achieving agile and sustainable sourcing networks in the plastic industry supply chain.

4.2.7. MICMAC analysis

MICMAC analysis is a widely recognized variant of the cross-impact analysis method, first introduced by Duperrin and Godet in 1973. MICMAC stands for 'Matrice d'Impacts Croisés Multiplication Appliqués

Table 2
Enablers of agile and sustainable sourcing.

S. No.	Enabler	Abbreviation	Brief description	Supporting literature
1	Risk hedging	RH	Risk hedging is a strategy to mitigate risks in sourcing networks, improving performance and resilience in disruptions like natural disasters, economic crises, or pandemics. It identifies critical vulnerabilities and develops contingency plans to build resilient sourcing networks.	Liu and Wang (2019); Myamba and Nguni (2022); Um and Han (2021)
2	Innovation	IN	Companies adapt product designs to meet market demands, fostering innovation to continuously produce new value. Agility and sustainability benefits are achieved if suppliers are incentivized to develop market-ready innovations.	Du et al. (2020); Kusi-Sarpong et al. (2019); Solaimani and van der Veen (2022)
3	Visibility	VI	Visibility in the sourcing networks enables tracking commodities and products in transit, providing a clear inventory picture. It helps shippers provide better customer service, reduce costs, streamline operations, and mitigate risks. Improved visibility eliminates material buffers, enhancing overall performance.	Baah et al. (2022); Finkinstadt and Handfield (2021); Rogerson and Parry (2020)
4	Resource utilization	RU	Improved resource utilization leads to sustainable development, reducing waste, forming strategic plans, and achieving social, environmental, and economic goals.	Digalwar et al. (2020); Pavlov et al., 2019a; Xie et al. (2020)
5	Process integration	PI	Process integration enables the cooperation between purchasers and vendors, including product creation in tandem or using a unified set of tools. This integration is driven by businesses controlling core competencies and outsourcing tasks, as the global interconnectedness demands increased reliance on suppliers and alliance collaboration.	Agarwal et al. (2007); Chen et al. (2009); Rajaguru and Matanda (2019)
6	Technological capability	TC	Information and communication technology transform the supply chain by enabling two-way data exchange between buyers and sellers. This virtual supply chain focuses on information, allowing entities to act on accurate data rather than chaos in complex sourcing networks.	Digalwar et al. (2020); Govindan et al. (2013); Yadav and Kumar (2022)
7	Best use of management tools	BM	Management tools such as JIT, Kanban, Poke Yoke, and Six Sigma can enhance decision-making and asset utilization. Organizations should optimize their usage as they are commonly used and can provide a competitive edge.	Chen and Wang (2022); Pötters et al. (2018); Valamede and Akkari (2020)
8	Suppliers as partners	SP	A firm's success relies on its suppliers, who can help businesses save costs and remain strong when treated like partners. Supplier and vendor participation is crucial for achieving agile and sustainable benefits, facilitating learning and development, and creating the synergy that improves supply chain performance.	Chicksand (2015); Ghadimi et al. (2018); Faruquee et al. (2021)
9	Collaboration	CO	Collaboration involves working with outside parties, such as suppliers, to achieve goals like learning and development. It creates a synergy that improves environmental capabilities. Supply networks can benefit from collaboration through reduced costs and uncertainty.	Ali et al. (2022); Ghazal and Alzoubi (2021); Yang et al. (2022)
10	Government regulations	GR	Governments are implementing stricter environmental and social regulations to ensure sustainable development. Agile and sustainable sourcing practices demonstrate commitment to regulatory compliance, responsible supply chain management, and corporate social responsibility.	Govindan and Hasanagic (2018); Sarkis (2020); Zhu and Sarkis (2006)
11	HR practices	HR	Management recognizes that wasteful use of resources, both material and human, is the root of the problem. Proper training on sustainability components will make employees more receptive to agility.	Manzoor et al. (2019); Jerónimo et al. (2020); Wang et al. (2020)
12	Cost reduction	CR	The improvements achieved by a firm's suppliers, such as decreased rework, scrap, and downtimes, contribute to improvements in the total cost of goods sold to purchasing organizations. Cost reduction helps businesses cut operational expenses and gain a competitive edge.	Govindan et al. (2013); Rout et al. (2021); Tseng et al. (2015)
13	Service level	SL	Enhancing customer service is crucial for supply chain performance, as it improves overall customer experience. Supply chain managers must adopt a strategic approach and build capabilities to provide services beyond the value chain to achieve this.	Guan et al. (2020); Rout et al. (2021); Zheng et al. (2020)
14	Lead time	LT	Lead time refers to the time between order and delivery. Time-based competitiveness is achieved by shortening supply, manufacturing, and distribution chain lead times. To reduce lead time eliminate bottlenecks in the system while sourcing items.	Baramichai et al. (2007); Sarkar et al. (2022); Taheri-Bavil-Oliaei et al. (2021)
15	Delivery	DL	Delivery refers to transporting goods from source to destination, critical to supply chain management. Efficient delivery processes are crucial to meet customer demands and maintain the smooth flow of goods. Companies specialize in managing and optimizing delivery operations to ensure on-time delivery.	Janvier-James (2012); Koshta et al. (2022); Xu et al. (2020)
16	Quality	QU	Business organizations prioritize quality in the global economy, recognizing the importance of supplier participation in enhancing quality and fulfilling customer requirements. Strong relationships with customers and vendors are crucial for good quality management. Working together leads to outstanding contributions from suppliers towards overall quality improvements.	Chau et al. (2021); Govindan et al. (2013); Lim et al. (2022)
17	Flexibility	FL	Flexibility in sourcing is crucial in today's uncertain business environments, enabling supply chains to adapt quickly and easily to changing market conditions. It offers advantages such as seasonality, low output, poor supplier performance, and new product introductions.	Kazancoglu et al. (2022); Li et al. (2017); Singh et al. (2019)
18	Knowledge management	KM	Knowledge is seen as a resource by many experts in their fields. Knowledge management is the capacity to effectively assimilate and execute changes based on agility and sustainability concerns. The workforce's level of knowledge and keenness determines the effectiveness of these strategies.	Gaviria-Marin et al. (2019); Lim et al. (2017); Schniederjans et al. (2020)
19	Global sourcing	GS	Global sourcing strategy involves managing logistics, R&D, manufacturing, and marketing interfaces globally. Companies must capitalize on their suppliers' locational advantages to remain competitive in the global marketplace.	Oshri et al. (2009); Roy and Sivakumar (2012); Trent and Monczka (2005)

Table 3
CVR scores of all the enablers.

S. No.	Enabler	N _{PE}	CVR	Decision
1	Risk hedging	6	0.71	Retained
2	Innovation	5	0.43	Retained
3	Visibility	6	0.71	Retained
4	Resource utilization	6	0.71	Retained
5	Process integration	7	1.00	Retained
6	Technological capability	7	1.00	Retained
7	Best use of management tools	3	-0.14	Rejected
8	Suppliers as partners	7	1.00	Retained
9	Collaboration	2	-0.43	Rejected
10	Government regulations	7	1.00	Retained
11	HR practices	4	0.14	Rejected
12	Cost reduction	7	1.00	Retained
13	Service level	7	1.00	Retained
14	Lead time	7	1.00	Retained
15	Delivery	4	0.14	Rejected
16	Quality	7	1.00	Retained
17	Flexibility	5	0.43	Retained
18	Knowledge management	6	0.71	Retained
19	Global sourcing	5	0.43	Retained

à un Classement' (Matrix for Cross-Impact Multiplication Applied to Classification). MICMAC is a valuable tool for enhancing the methodological rigor of studies that employ the ISM. Many scholars have recognized the importance of incorporating MICMAC analysis alongside ISM to evaluate the interdependence of variables within a network (Kumar et al., 2023; Tan et al., 2019; Wu et al., 2022).

The utilization of MICMAC analysis in this research aims to identify and evaluate the enablers based on their driving and dependence powers toward the agility and sustainability of sourcing networks (Agrawal, 2019). The conical matrix (presented in Table 8) serves as the starting

Table 4
SSIM.

Enablers	15	14	13	12	11	10	9	8	7	6	5	4	3	2
1	X	A	A	V	O	O	O	A	A	O	A	A	A	V
2	A	A	X	O	O	O	V	O	A	A	A	O	O	
3	O	O	O	O	V	V	O	O	O	A	O	O		
4	O	X	X	V	V	V	V	O	O	A	X			
5	X	O	O	O	O	O	O	O	A	A				
6	O	O	O	O	V	V	V	O	V					
7	X	O	V	V	V	V	V	O						
8	A	V	O	V	O	O	O							
9	A	A	O	A	O	O								
10	A	O	A	V	A									
11	O	O	O	O										
12	A	A	O											
13	X	A												
14	O													

Table 5
IRM.

Enablers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	1
2	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0
3	1	0	1	0	0	0	0	0	0	1	1	0	0	0	0
4	1	0	0	1	1	0	0	0	1	1	1	1	1	1	0
5	1	1	0	1	1	0	0	0	0	0	0	0	0	0	1
6	0	1	1	1	1	1	1	0	1	1	1	0	0	0	0
7	1	1	0	0	1	0	1	0	1	1	1	1	1	0	1
8	1	0	0	0	0	0	0	1	0	0	0	1	0	1	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
11	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
12	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
13	1	1	0	1	0	0	0	0	0	1	0	0	1	0	1
14	1	1	0	1	0	0	0	0	1	0	0	1	1	1	0
15	1	1	0	0	1	0	1	1	1	1	0	1	1	0	1

point for this analysis. The driving and dependence powers of the enablers are calculated by aggregating the values of cells with a '1' across the rows and columns, respectively (refer to Table 9). Subsequently, a graph is constructed to depict the relationship between the driving and dependence powers of the enablers. Based on the strength of their driving and dependence powers, the enablers are categorized into four groups: autonomous, dependent, linkage, and driver enablers. Fig. 3 displays the quadrant of the enablers having these four groups.

4.2.7.1. Cluster I: Autonomous enablers. Low levels of driving and dependence powers characterize the first set of enablers. In our case, only one enabler lies in this category, i.e., VI. Although this enabler is weakly coupled to other enablers, it is significant enough to impact the supply chain performance; thus, it is treated as the autonomous enabler. In other words, it is less challenging to handle this enabler as it is not complexly linked with others while achieving the ultimate goal.

4.2.7.2. Cluster II: Dependent enablers. This cluster comprises enablers with strong dependence powers but weak driving powers. IN, CR, SL, LT, and QU become part of this cluster. The achievement of this set of enablers is highly dependent on others, but these enablers contribute weakly to other enablers in the system. These enablers typically serve the ultimate objective that a company aims to attain, in our case, supply chain performance.

4.2.7.3. Cluster III: Linkage enablers. This set of enablers is characterized by high dependence and high driving powers. They are highly linked and intertwined in the system. In the present context, RH, RU, FL, and GS are grouped in this cluster. These enablers are said to be highly interdependent and influential in the system. They are critical to handle as any slight change in their behavior will severely impact the entire system.

Table 6
FRM.

Enablers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	0	0	1*	0	1*	1*	1*	1*	0	1	1*	0	1
2	0	1	0	1*	0	0	0	0	1	1*	0	0	1	0	1*
3	1	1*	1	0	0	0	0	0	0	1	1	1*	0	0	1*
4	1	1*	0	1	1	0	0	0	1	1	1	1	1	1	1*
5	1	1	0	1	1	0	1*	1*	1*	1*	1*	1*	1*	1*	1
6	1*	1	1	1	1	1	1	0	1	1	1	1*	1*	1*	1*
7	1	1	0	1*	1	0	1	1*	1	1	1	1	1	0	1
8	1	1*	0	1*	0	0	0	1	1*	0	0	1	1*	1*	1*
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	1*	1	0	1	0	0	0
11	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
12	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
13	1	1	0	1	1*	0	1*	1*	1*	1	1*	1*	1	1*	1
14	1	1	0	1	1*	0	0	0	1	1*	1*	1	1	1	1*
15	1	1	0	1*	1	0	1	1	1	1	1*	1	1	0	1

Table 7
Levels of enablers.

Enablers	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,2,5,7,8,9,10,12,13,15	1,3,4,5,6,7,8,13,14,15	1,5,7,8,13,15	V
2	2,4,9,10,13,15	1,2,3,4,5,6,7,8,13,14,15	2,4,13,15	IV
3	1,2,3,10,11,12,15	3,6	3	VI
4	1,2,4,5,9,10,11,12,13,14,15	2,4,5,6,7,8,13,14,15	2,4,5,13,14,15	VI
5	1,2,4,5,7,8,9,10,11,12,13,14,15	1,4,5,6,7,13,14,15	1,4,5,7,13,14,15	VIII
6	1,2,3,4,5,6,7,9,10,11,12,13,14,15	6	6	IX
7	1,2,4,5,7,8,9,10,11,12,13	1,5,6,7,13,15	1,5,7,13	VIII
8	1,2,4,8,9,12,13,14,15	1,5,7,8,13,15	1,8,13,15	VII
9	9	1,2,4,5,6,7,8,9,10,12,13,14,15	9	I
10	9,10,12	1,2,3,4,5,6,7,10,11,13,14,15	10	III
11	10,11	3,4,5,6,7,11,13,14,15	11	IV
12	9,12	1,3,4,5,6,7,8,10,12,13,14,15	12	II
13	1,2,4,5,7,8,9,10,11,12,13,14,15	1,2,4,5,6,7,8,13,14,15	1,2,4,5,7,8,13,14,15	IV
14	1,2,4,5,9,10,11,12,13,14,15	4,5,6,8,13,14	4,5,13,14	VI
15	1,2,4,5,7,8,9,10,11,12,13,15	1,2,3,4,5,6,7,8,13,14,15	1,2,4,5,7,8,13,15	IV

Table 8
Conical matrix.

Enablers	9	12	10	2	11	13	15	1	3	4	14	8	5	7	6
9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
2	1	0	1	1	0	1	1	0	0	1	0	0	0	0	0
11	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
13	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0
15	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0
1	1	1	1	1	0	1	1	1	0	0	0	1	1	1	0
3	0	1	1	1	1	0	1	1	1	0	0	0	0	0	0
4	1	1	1	1	1	1	1	1	0	1	1	0	1	0	0
14	1	1	1	1	1	1	1	1	0	1	1	0	1	0	0
8	1	1	0	1	0	1	1	1	0	1	1	1	0	0	0
5	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0
7	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0
6	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1

4.2.7.4. *Cluster IV: Driver enablers.* These enablers possess high driving powers but relatively lesser dependence. Though independent, they play a significant role in driving other enablers in the system. The set comprises PI, TC, SP, GR, and KM. Being the major drivers, these enablers are crucial from the decision-makers’ perspective. Thus, these enablers require the necessary attention when aiming for agile and sustainable sourcing networks in the supply chain of the plastic industry.

5. Results and discussion

The results of the present study show that all the identified enablers help achieve agile and sustainable sourcing networks in some way or other.

When it comes to pushing change, the top-level enablers depend heavily on the support of other enablers because of their limited driving powers. Cost reduction, quality, and service level are the performance level enablers that are critical to agile and sustainable sourcing networks in the plastic industry. It can be observed from the Digraph that these enablers depend on the other operational level enablers, such as innovation, lead time, flexibility, and global sourcing. Innovation and flexibility happen when risk is mitigated, lead time gets reduced on account of visibility and flexibility, and global sourcing and flexibility are the pair outcomes of each other. In this way, flexibility is relatively more intertwined with other enablers. Nonetheless, flexibility is a significant component of an agile and sustainable supply chain (Kazancoglu et al., 2022; Vickery et al., 1999).

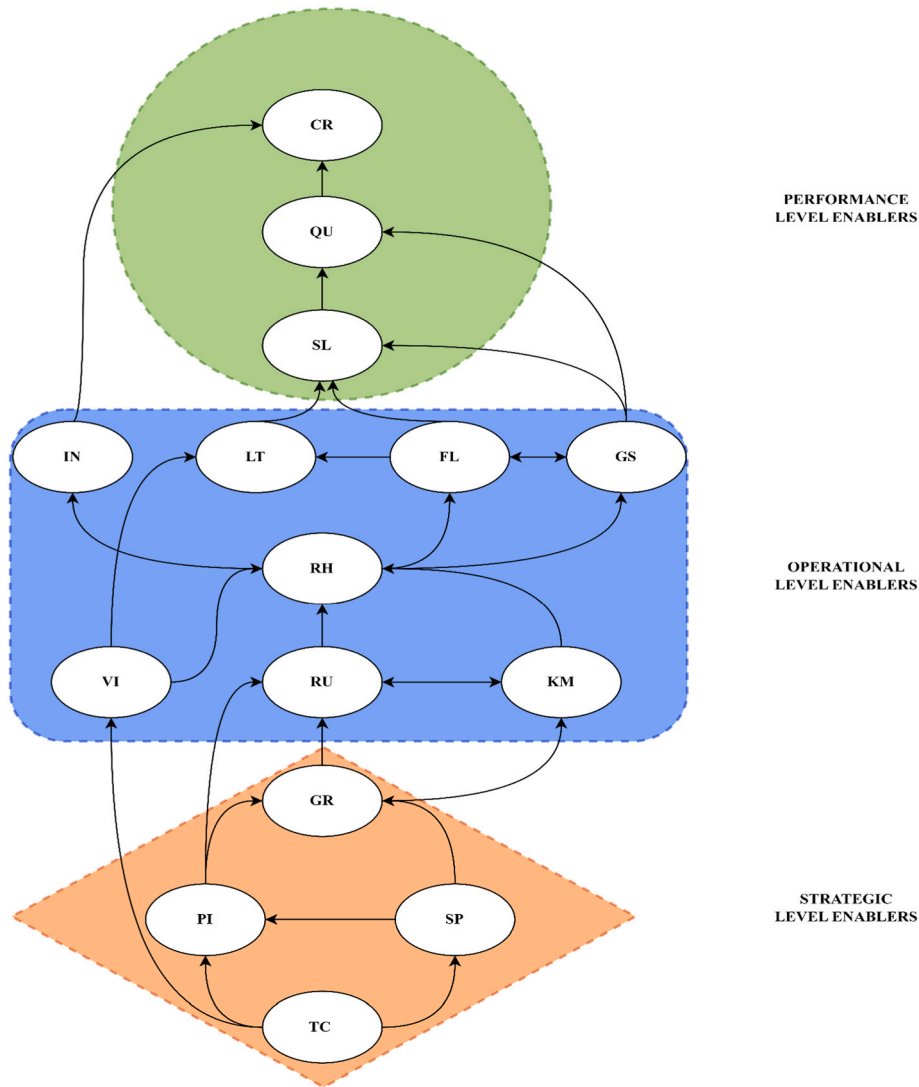


Fig. 2. Digraph positioning the enablers into different levels.

Table 9
Driving and dependence powers of the enablers.

Enablers	9	12	10	2	11	13	15	1	3	4	14	8	5	7	6	Driving Power
9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
12	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
10	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	3
2	1	0	1	1	0	1	1	0	0	1	0	0	0	0	0	6
11	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2
13	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	13
15	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	12
1	1	1	1	1	0	1	1	1	0	0	0	1	1	1	0	10
3	0	1	1	1	1	0	1	1	1	0	0	0	0	0	0	7
4	1	1	1	1	1	1	1	1	0	1	1	0	1	0	0	11
14	1	1	1	1	1	1	1	1	0	1	1	0	1	0	0	11
8	1	1	0	1	0	1	1	1	0	1	1	1	0	0	0	9
5	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	13
7	1	1	1	1	1	1	1	1	0	1	0	1	1	1	0	12
6	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	14
Dependence Power	13	12	12	11	9	10	11	10	2	9	6	6	8	6	1	

The bottom-level enablers are not the less important ones; they drive the whole system. The technological capability of the firms is one of the significant attributes of success in the modern business world (Digalwar et al., 2020; Yadav & Kumar, 2022). It helps collaborate with suppliers, integrates the processes, and makes the sourcing networks visible.

Moreover, government regulations emerge when the firms contract to source different kinds of products. These regulations are necessary to avoid adverse impacts on the business environment and society, helping the nation deal with the economic crisis and achieve prosperity (Contractor et al., 2020; Luthra et al., 2013). This research found that

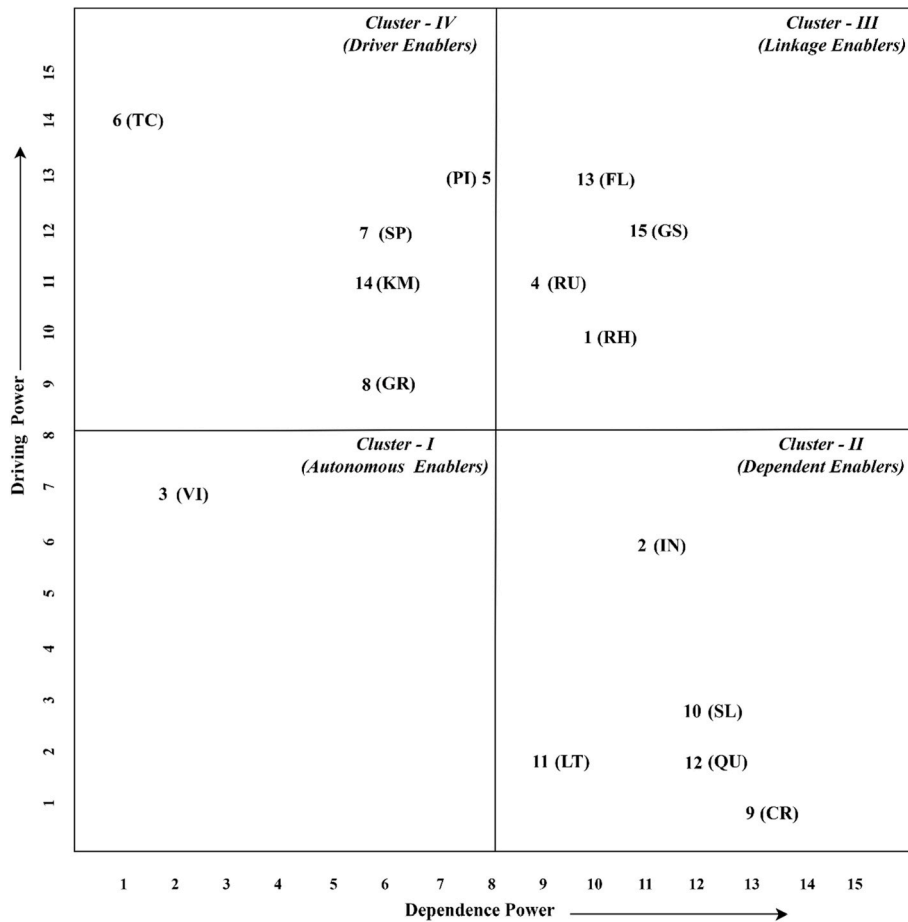


Fig. 3. MICMAC graph.

these enablers are strategic level enablers and are crucial to driving the entire sourcing networks to become agile and sustainable. Only by enhancing these foundational components can a firm’s performance be achieved.

Further, the existence of a few enablers may provide interdependent action plans. For instance, resource utilization and knowledge management have sufficient degrees of both driving and dependence powers. The management requires constant monitoring of these enablers. Even a slight change in their levels may significantly influence agility and sustainability. Hence, the proper utilization of resources and the acquired knowledge of supply chain staff and executives, including other criteria, are essential to shift towards agile and sustainable sourcing in the plastic industry.

5.1. Validation of the findings

As we know, the objectives of this study were to propose a causal model comprising the functionalities of the enablers and to categorize them in terms of their driving and dependence powers. These objectives were fulfilled by developing the Digraph and performing the MICMAC analysis. Our next task was to validate these findings obtained through the implemented methodology. Thus, we again contacted the experts chosen for the study to know their perceptions of enablers. They were asked to rate the enablers twice. Once, they rated the enablers’ functionalities, whether a particular enabler was a strategic, operational, or performance level enabler. It was presumed valid if a particular enabler obtained five favorable opinions from seven experts to belong to a particular category. After obtaining the experts’ ratings for all the enablers, we found that the results were almost close to what was represented by the Digraph. The strategic level enablers were technological

capability, process integration, suppliers as partners, and government regulations. The operational level enablers were visibility, resource utilization, knowledge management, risk hedging, innovation, flexibility, and global sourcing. The performance level enablers were lead time, service level, quality, and cost reduction. Here, the lead time is perceived as the performance level enabler by the experts, though it falls in the category of operational level in the Digraph. We can understand from the Digraph that it is in the upper level of the operational category, so it is also significantly closer to playing the role of performance level enabler.

The experts were again requested to score the enablers on a scale of 1–15 according to their driving and dependence strengths. The scores obtained were plotted on the graph with a middle division 8. We found that enablers were categorized as follows: (a) visibility as an autonomous enabler, (b) innovation, service level, quality, cost reduction, and lead time as dependent enablers, (c) risk hedging, resource utilization, global sourcing, flexibility, and process integration as linkage enablers, and (d) technological capability, suppliers as partners, knowledge management, and global sourcing as driver enablers. Here, we notice that all the enablers fell under the same categories obtained through the MICMAC analysis. Only one enabler, i.e., process integration, fell under the category of linkage enablers as per the perception score of experts. Hence, process integration possesses high driving and dependence powers, as also closely depicted in the MICMAC graph. These validations of the findings obtained through the present study establish the robustness and credibility of the model proposed for agile and sustainable sourcing networks in the plastic industry supply chain.

6. Implications of the study

6.1. Contributions to literature

This study contributes to the literature in several ways. First, it is one of the initial studies integrating agile and sustainable sourcing principles in a single framework. Research needs to integrate agile and sustainable criteria to address the present generation's fast-changing needs while maintaining future generations' needs (Akhtar et al., 2023; Ciccullo et al., 2018). Fifteen enablers are determined through the comprehensive literature study and expert opinions validated in the present context. These enablers provide the theoretical foundation for the existing literature on the factors responsible for agile and sustainable sourcing. Second, the rigorous ISM approach provides methodical findings to the research gaps identified in the literature. The developed ISM hierarchy provides the interrelationships among the identified enablers. Researchers could benefit from the defined contextual relationships and utilize these criteria for different agile and sustainable sourcing network perspectives.

Third, as per our extensive literature search, it is the first study contributing to the literature on agility and sustainability that proposes a conceptual model positioning the enablers as per their functionalities in the agile and sustainable sourcing networks, i.e., strategic, operational, and performance level enablers. The enablers segregated based on these functionalities clearly outline their role in executing a well-functioning supply chain. Finally, these enablers are classified into different clusters per their driving and dependence powers. Such a grouping helps decide which set of enablers to target and to what extent since their degree of sensitivity is different, having different levels of driving and dependence powers. Accordingly, suitable strategies may be formulated based on their functionalities and the division of enablers into clusters.

6.2. Implications to the plastic industry

The findings of the present study have significant implications for the plastic industry and related firms. Agility and sustainability are crucial due to changing market dynamics, customer needs, and environmental conditions. Managers need strategies to adjust sourcing decisions rapidly. Technological capability, process integration, supplier partnerships, and government regulations are critical strategic enablers that drive agility and sustainability. Investing in process integration, fostering supplier partnerships, embracing technology, and adhering to regulations can improve the sourcing network's agility and sustainability. Managers should stay updated on regulations and ensure compliance throughout the sourcing network. Adhering to regulations can enhance the company's reputation, mitigate risks, and open up opportunities for sustainable sourcing practices. Visibility, resource utilization, and knowledge management are key operational-level enablers that help mitigate risks and achieve risk hedging throughout the sourcing network. Managers should invest in systems that enhance visibility into the supply chain, optimize resource utilization, and promote knowledge sharing among management and staff. Comprehensive risk hedging and contingency planning can enhance resilience and minimize vulnerabilities in the sourcing network. Managers should seek innovative sourcing approaches, adopt flexible strategies, and explore global sourcing opportunities to gain a competitive advantage. The sourcing network's lead time can be reduced by making it visible and flexible, allowing it to better respond to uncertainties and disruptions. Service level, quality, and cost reduction are performance-level enablers, but they depend on effectively implementing other enablers in the hierarchy. Managers can improve service levels, ensure product quality, and optimize costs by focusing on the bottom-level enablers.

Since visibility is an autonomous enabler, managers should prioritize maintaining and enhancing visibility throughout the supply chain. Investing in advanced tracking and monitoring technologies, data

analytics tools, and real-time information sharing platforms can help. Enablers with high driving powers but relatively lesser dependence, such as process integration, technological capability, suppliers as partners, government regulations, and knowledge management, play a crucial role in driving the overall supply chain performance. Collaborative strategies, such as joint development programs or supplier engagement initiatives, can promote knowledge sharing, innovation, and incorporation of other enabling criteria into sourcing decisions. The enablers with high dependence and driving powers (risk hedging, resource utilization, flexibility, and global sourcing) are highly influential and interconnected. Managers should focus on strengthening these enablers as any changes or improvements in their behavior can significantly impact the entire sourcing network. It may require close collaboration with suppliers, robust risk management strategies, and adapting to dynamic market conditions. Continuous performance monitoring and analysis are necessary to implement an adaptive decision-making approach. Establishing appropriate metrics and KPIs is crucial to managing the different enablers effectively. Cross-functional collaboration within the organization is necessary to successfully implement agile and sustainable sourcing networks.

Finally, agile and sustainable sourcing practices contribute to long-term value creation by considering the triple bottom line of people, planet, and profit (Khan et al., 2021). These practices can drive cost savings while serving society and the environment. These cost savings translate into improved financial performance and increased market base, positioning organizations for long-term success. It ensures the continuity of supply, protects brand reputation, and creates a competitive advantage in the marketplace. Also, managers must proactively identify and manage environmental, social, and governance (ESG) issues in the supply chain (Huang, 2021). Embracing agile and sustainable sourcing practices is essential in mitigating potential disruptions caused by climate change, resource scarcity, or regulatory effects. These implications will lay a strong foundation for agility and sustainability goals.

7. Conclusions, limitations, and future research

This study aims to model agile and sustainable sourcing practices in the plastic industry. A comprehensive study of the relevant literature is performed to identify the enablers validated by the Delphi technique. A conceptual model is proposed after a rigorous, methodical approach and analysis of the enablers. The ISM approach serves as it organizes complicated problems and gives decision-makers a realistic view of a situation and its components. Unlike other methods, ISM integrates participants' diverse perceptions, handles complex systems, is heuristic in nature, and yields insights into system behavior. The proposed model is applicable in the context of agile and sustainable sourcing practices as it classifies the enablers into strategic, operational, and performance level functionalities. Further, MICMAC analysis clusters the enablers based on their driving and dependence strengths. The enablers are organized into four distinct clusters, i.e., autonomous, dependent, linkage, and driver enablers, as per their varying degrees of driving and dependence powers. Thus, firms may devise different strategies suitable for different sets of enablers.

The present study provides several implications for academia and practitioners. The supply chain managers must have a firm grasp of the traits and interdependencies of the variables that serve as enablers to devise methods for strengthening the sourcing networks' agility and sustainability. Technological capability, process integration, suppliers as partners, and government regulations must be strategically decided within the framework. They serve as a propellant for knowledge management, resource utilization, and supply chain visibility. With these achievements, the risk is mitigated, which further leads to innovation of processes and products, reduction in lead time, and facilitate flexibility and sourcing from across the globe. When these enablers are adequately handled, the service level of the complete sourcing network is improved,

the quality of the products and services is enhanced, the cost is reduced substantially, and ultimately, the whole supply chain starts performing effectively.

The limitations of this study open new avenues for further research and investigations. Thus, potential research areas that future scholars could explore are as follows:

- We have yet to explore various sourcing approaches in this study while formulating agile and sustainable sourcing networks. Future studies could compare the findings in different approaches, such as single-sourcing, dual-sourcing, or multi-sourcing. An in-depth analysis of agile and sustainable sourcing networks in different sourcing approaches can be conducted to examine their impact on supply chain performance. Factors such as transportation costs, inventory levels, and supplier reliability should be considered when comparing single, dual, and multi-sourcing approaches. The studies could also employ simulation models or mathematical optimization techniques to identify the most agile and sustainable sourcing approach for the plastic industry.
- Future research can explore the challenges and opportunities of implementing circular economy practices within the sourcing networks. In this line, Ayati et al. (2022) analyzed the barriers to implementing a circular supply chain based on three recovery approaches: remanufacturing, reusing, and recycling. Future research could analyze these barriers in different contexts and investigate successful cases where remanufacturing, reusing, and recycling have been integrated into the sourcing networks of different firms. Furthermore, the studies could explore potential constraints, such as consumer behavior and technological limitations, that may hinder the transition to a circular economy model. The focus should be on strategies to reduce waste, promote the reuse of plastic materials, and the prospect of closed-loop supply chains.
- Although we have interacted with the experts (managers of a firm) as a requirement of this study, future researchers can understand the perspectives of different stakeholders regarding agile and sustainable sourcing in the plastic industry. Apart from the manufacturers, the stakeholders will include consumers seeking eco-friendly products, investors looking for sustainable businesses, and policymakers concerned with agility and sustainability. Research could explore the challenges, motivations, and incentives influencing their decisions and actions.
- In future studies, a carbon footprint analysis could be performed regarding the sourcing in the plastic industry. Plastics have a substantial carbon footprint, accounting for 3.4% of worldwide greenhouse gas emissions (OECD, 2023). A comprehensive carbon footprint analysis involves mapping and quantifying greenhouse gas emissions throughout the supply chain. It can be accomplished using a life cycle assessment (LCA) methodology to examine the environmental impact of each stage, including raw material extraction, production, transportation, usage, and end-of-life treatment. Future studies could also propose carbon reduction strategies, such as adopting renewable energy resources and optimizing transportation routes to minimize emissions.
- The present study is conducted by looking into the case of a single industry. Experts of that industry were sought to determine the enablers and establish the contextual relationships. There could be a judgement bias as the expert opinion could be lopsided towards the experience of a single industry. Thus, exploring more industries would be a rigor to the findings.
- The proposed model could be tested statistically by collecting primary or secondary data in different contexts. Various statistical approaches, like multiple regression, hierarchical regression, structural equation modeling (SEM), etc., may be utilized to assess the reliability and validity of the model.
- Finally, research in the area should assess the usage of alternative materials, including bioplastics and recycled polymers, compared to

traditional petroleum-based plastics. It could involve identifying the eco-friendly alternatives, evaluating their performance, cost-effectiveness, and environmental impact, and assessing the challenges and opportunities in sourcing these materials.

(Note: The partition matrix for all the nine iterations assigning the levels to the enablers is provided in the supplementary file).

CRediT authorship contribution statement

Mohd Ziyauddin Khan: Conceptualization, Investigation, Methodology, Writing – original draft. **Ashwani Kumar:** Conceptualization, Investigation, Methodology, Supervision, Writing – review & editing. **Yang Liu:** Conceptualization, Methodology, Supervision, Validation, Writing – review & editing. **Piyush Gupta:** Validation, Writing – review & editing. **Dheeraj Sharma:** Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jclepro.2023.140522>.

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