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Barriers and overcoming strategies to supply chain sustainability innovation

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Abstract – This study identifies a list of barriers that hinders adoption, implementation and upscaling of sustainable supply chain innovation in the manufacturing industry. It further proposes overcoming strategies that seek to aid management decision to dealing with these barriers systematically. A multi-criteria decision analysis method, the Best-Worst Method (BWM), is adopted to aid in the evaluation and prioritisation of the barriers and their overcoming strategies within the Indian manufacturing industry, an emerging economy. The results depict that, "lack of technical expertise and training", "lack of R&D and innovation capabilities", "popularity of traditional technology", "high initial investment in latest technology" and "fear of extra workload and loss of flexibility" are the top five barriers that confronts the Indian manufacturing companies in their quest for adopting and implementing sustainable supply chain innovation practices. In addition, the overcoming strategic pathway for dealing with these barriers are provided. The findings provide managerial and policy insights for guiding the formation of strategic operations framework and resource allocation if these Indian manufacturing firms seeks to build sustainability into their supply chain innovations.

***Keywords*:** Supply chain sustainability; innovation management; barriers; overcoming strategies; Best-worst method.

1. Introduction

Industrial activities have given rise to global environmental impacts and damage to human life (Chen, 2008; Badri Ahmadi et al., 2017a). This rising negative global environmental issues has forced many stakeholder groups including policy experts and environmental activists to advocate for a more and increasingly tougher governmental regulations (Khan et al., 2018; Kumar and Dixit, 2018 a, b; Luthra et al., 2017). Governments have responded to these calls by instituting much stricter rules and regulations to mandate industries and companies to adhere to certain sustainability standards (Bai et al., 2019; Hassini et al., 2012). Responding to these multi-stakeholder concerns and pressures is imperative for the progress of sustainable development agenda (Badri Ahmadi et al., 2017a; Kusi-Sarpong et al., 2019a). Organizations have therefore started to integrate sustainability in their operations and supply chains (Bai and Sarkis, 2018; Badri Ahmadi et al., 2017b). Firms have not only started to react

to pressures from these multi-stakeholders but also realized the benefits and importance of sustainability for building competitive advantage (Bai et al., 2017; Bai et al., 2019).

The quest for sustainability has started to change the competitive landscape forcing organizations and supply chains to rethink their processes, technologies, products, and business models (Nidumolu et al., 2009). Sustainable manufacturing and development (industrial ecology) is a pathway to sustainability (Sabaghi et al., 2016). The key to advancing and achieving the sustainability goal by organizations and supply chains is through sustainable innovation practices (Kusi-Sarpong et al., 2019a; Gupta and Barua, 2018a). Sustainable innovation can be considered or defined as the introduction of modified or novel practices into production processes, technologies, products techniques, and organizational systems with the focus on lessening environmental damage (Kusi-Sarpong et al., 2019a). These sustainable innovation practices should provide similar or even much greater value for organizations with enhanced socio-economic and organizational performance (Horbach, 2005; Hafkesbrink and Halstrick-Schwenk, 2005). Sustainable innovation strategies can aid organizations in dealing with sustainability issues within their manufacturing processes and supply chains (Cai and Zhou, 2014; Isaksson et al., 2010).

Yet, firms are not finding it easy when implementing sustainable supply chain innovation. These organizations face lots of barriers when attempting to innovate for sustainability (Laukkanen and Patala, 2014). These barriers are required to be identified and addressed to enable adoption, implementation and upscaling of supply chain sustainability innovations. However, it is practically impossible for these organizations to simultaneously eliminate all these barriers due to scarcity of resources available to them. Therefore, these organizations are required to develop effective strategies that can provide a pathway for mitigating these barriers. This requires the need for these organizations to initially identify the sources of these

barriers, analyze the barriers and provide some solutions to deal with them (Nidumolu et al., 2009; Gupta and Barua, 2018a, Gupta et al., 2017).

Many studies have investigated green and sustainable innovation (see e.g. Amore and Bennedsen, 2016; Gupta and Barua, 2017, 2018a, 2018b; Hafkesbrink and Halstrick-Schwenk, 2005; Hellström, 2007; Huang and Li, 2015; Tseng and Chiu, 2012); others on drivers to green and sustainable innovation (Chen, 2008; Cai et al., 2014), with a recent study on sustainable supply chain innovation (Kusi-Sarpong et al., 2019a). Yet, to date, studies specific to the identification of the barriers and overcoming strategies for achieving sustainable supply chain innovation adoption, implementation and upscaling is scant.

Equipping supply chain actors with a better understanding of the nature of these barriers and overcoming strategies is expected to offer them better pathways for dealing with the barriers and influencing change towards supply chain sustainability innovation goals. This paper, therefore, proposes a framework composed of various barriers that can have an impact on the adoption, implementation and upscaling of sustainable supply chain innovation and it develops strategies to overcome these barriers. More specifically, the objectives of this paper are:

- To identify and rank the barriers that may hinder sustainable supply chain innovation adoption, implementation and upscaling.

- To identify, evaluate and rank the overcoming strategies with respect to the barriers to sustainable supply chain innovation adoption, implementation and upscaling.

- To provide practical insights in the applicability of this model within an emerging economy.

4

To best address these objectives, a multi-case approach from the Indian manufacturing sector and supply chains is adopted. India and manufacturing supply chains context were chosen because of the industry's recent and potential future growth (Mehta and Rajan, 2017). This sector, in India, is one of the fastest growing sectors with revenue potentially reaching US$ 1 trillion by 2025 (Kusi-Sarpong et al., 2019a; Jakhar et al., 2018). This case-based investigation will provide managerial insights and guidelines for aiding the sector in dealing with these barriers.

The paper proceeds with the following structure. Literature review and framework development are discussed in Section 2, and research methodology comprising of the methods in aiding the evaluating of the barriers and prioritization of the overcoming strategies are presented in Section 3. The case study application and results are presented in Section 4. Discussions of the results is done in Section 5. Section 6 provides implications of the study. Limitations and future research directions are elaborated in Section 7.

2. Literature background and framework development

2.1. Sustainable Supply Chain Management (SSCM)

This section introduces the concept and definition of sustainable supply chain management. Sustainable supply chain management (SSCM) can be defined as the process of controlling and managing of information, material and capital flow and the co-operation among firms along the supply chain taking into consideration the triple-bottom-line dimensions (i.e. economic, social and environmental) of sustainable development simultaneously derived from customer and stakeholder requirements (Seuring and Müller, 2008a; Lin and Tseng, 2016; Reefke and Sundaram, 2018). In other words, SSCM is characterized by the explicit integration of economic, social and environmental concerns into the planning and decision-making of supply chain management (Brandenburg et al., 2014;

Kusi-Sarpong et al., 2019a; Esfahbodi et al., 2016; Sarkis and Dhavale, 2015). Thus, the management of operations, resources, information and funds of supply chains to maximize *profits* whilst minimizing *environmental concerns* and maximizing *social wellbeing* (Kusi-Sarpong et al., 2019a; Hassini et al., 2012). SSCM helps to reduce the negative supply chain operations impacts and improves organizations efficiency from social, economic and environmental perspectives (Wong et al., 2014; Chacón Vargas et al., 2018). SSCM initiatives provide a means for firms to achieve a "win-win-win" sustainable outcome (Danese et al., 2018; Das, 2018). This means that firms that practice SSCM strive to meet multiple and conflicting objectives. As profits maximizing will mean reducing operational costs, minimizing environmental impacts and maximizing social well-being can call for additional costs (Hassini et al., 2012). This brings additional challenges and complicate sustainability-oriented decisions for supply chain managers by dealing with multi-actors along the supply chain when evaluating social benefits and environmental impacts (Sarkis and Dhavale, 2015). These decisions are broader in context, process and influence. SSCM can be linked to practices such as green design, production planning and control for remanufacturing, reverse logistics, energy use, inventory management, product recovery, waste management, and emission reduction (Zailani et al., 2012).

The need to consider the integration of sustainability into supply chains is partly due to the growing concerns and awareness of the public, stricter governmental policies, social activism, and market and customers pressures (Badri Ahmadi et al., 2017; Tseng at el., 2015; Luthra and Mangla, 2018; Kusi-Sarpong et al., 2019b). Firms have also started to integrate sustainability into their supply chains as a means to increase corporate brand and image, and manage supply chain risks such as environmental damages and labour disputes, which may improve business continuity and minimize supply chain disruptions and cost (Bai et al., 2019;

6

Gouda and Saranga, 2018; Speier et al., 2011; Ivanov et al., 2017). The operations of a supply chain member can affect that of other members (e.g. can cause severe supply chain disruptions (Tong et al., 2018)), especially to those downstream to that member. A typical example is if a supply chain member's employee's put up a strike actions, this can have severe impact not only on corporate brand and image of those downstream to this member (or even to the entire supply chain) but also on financial position, e.g. due to loss of sales (Speier et al., 2011; Ivanov et al., 2017). It is therefore imperative for supply chain members to integrate and manage sustainability in their operations in a coordinated manner (with other members on the chain) to improve the overall supply chain sustainability goal (Kusi-Sarpong et al., 2019b). Thus, multinationals and developed countries companies are expected to share and extend their sustainability initiatives and experiences with their counterparts from developing and emerging economies when forming supply chain partnerships for upscaling and advancing the achievement of the supply chain sustainability goal.

The cooperation between supply chain partners in the form of effective communication is essential for effective SSCM (Kusi-Sarpong at el., 2019b). The cooperation between supply chain members is not only important for communication but also facilitates the smooth implementation of programs such as environmental management systems, green products design, all of which are critical for achieving supply chains sustainability goals (Eltayeb et al., 2011; Zailani et al., 2012). Organizations adopting SSCM initiatives promote sustainable development which prepares them for a more global sustainability initiatives such as the UNSDGs which places much importance on sustainable production and consumption goal (Griggs et al., 2013).

2.2. Supply chain sustainability innovation

This section introduces the concept of sustainable innovation and various related studies. Sustainability is an important driver for supply chains and organizational innovation (Laukkanen and Patala, 2014; Nidumolu et al., 2009). In other words, sustainability is hinged on innovation (Kusi-Sarpong et al., 2019a). Organizations that seek to achieve sustainable supply chains must innovate in respond to the negative impacts (Klewitz and Hansen, 2014; Koberg and Longoni, 2019), especially from the socio-environmental perspective. For example, Silva et al. (in press) identified process and product innovation as a mediator of the relationship between sustainable supply chain practices and sustainability performance, reaffirming the importance of innovation. Sustainable innovation may be defined as modified product or production process changes that seek to minimize socio-environmental impact while increasing the triple-bottom-line (Kemp et al., 2001; Beise and Rennings, 2005; De Marchi, 2012). Previous studies have highlighted the importance and benefits of sustainable innovation in SSCM (e.g. Costantini et al., 2017; Gao et al., 2017; de Vargas Mores et al., 2018; Silva et al., in press). For example, one study has argued that sustainable innovation can benefit organizations in many ways including improving social image and profit, and reducing operational cost (Aguado et al., 2013). A more industrial specific sustainable innovation also occurs, such as in the chemical industry where sustainable innovation aids in improving feed stock and yields, reduce cost and increase market share from integrating sustainability into innovations (Kusi-Sarpong at al., 2019a). Risk management is also another important aspect of sustainable innovation. For example, firms that do not consider social factors as part of their product or process innovations may pass on more risk to their customers and may face more risk of losing their business than their counterparts (Iles and Martin, 2013; Hueske et al., 2015).

Yet, sustainable innovations by firms are confronted with many (severe) barriers, some of which may be due to the absence of appropriate policy frameworks for providing a systematic guidance to these organizations in their innovative processes. It may also be because strategies for overcoming these barriers are not tailored to the specific barriers faced by these organizations when attempting to innovate (Guerin, 2001). Successful innovation depends on the organization's combination of capabilities such as financial capability or access to finance, hiring high skilled-staffs, market knowledge, research and development (R&D), and establishing effective collaboration and cooperation with other supply chain partners (D'Este et al., 2012). However, having all these initiatives together and implementing them simultaneously is a difficult task to achieve. Therefore, firms may need to identify and prioritize the barriers that hinder them from achieving this goal and strategize to overcome these barriers accordingly.

2.3. Barriers to supply chain sustainability innovation

This section reviews various studies related to barriers to sustainable innovation. Sustainability innovation is increasingly being integrated into the manufacturing operations due to raising concerns of policy makers, manufacturers and other stakeholders (Stewart et al., 2016). Sensing the importance of sustainability innovation in operations, few studies have recently been conducted for developing sustainability innovation framework for manufacturing organizations (Gupta and Barua, 2017; Kusi-Sarpong et al., 2019a). Adopting, implementing an upscaling of sustainability innovations in operations and manufacturing organizations is not an easy task and are often married with some barriers. Few authors, although small in number have attempted to study the barriers to sustainability innovation. For example, Polzin et al. (2016) conducted a study to investigate how the institutional innovation intermediaries help in addressing the barriers to sustainable innovation through

financial mobilizations. They found out that financial mobilization activities such as policy and regulatory support for innovations, financial cooperation between public and private institutions, and presence of financial instruments can help policy makers, regulatory bodies, and sustainable policies to overcome and address technological, regulatory and financial barriers that hinder sustainable innovations. In another study, Cecere et al. (2018) analysed the impact of financial barriers on sustainable innovations. They examined the effect of public funding as well as other external and internal funding on innovations. The results indicate that, lack of internal funding acts as a major barrier for sustainability innovation, and lack of funding from public sources such as government institutions impedes sustainability innovation. On the contrary, lack of funding from other external sources does not impact much on sustainability innovation activities. de Jesus Pacheco et al. (2018) conducted an extensive literature review to identify the barriers to green and sustainable innovation. They identified few major barriers including lack of awareness and understanding among organizations about benefits of sustainable innovations, lack of skilled manpower to implement sustainable innovations, lack of customer acceptance and lack of awareness about sustainable products, lack of investment in research and development related to sustainable products and considering sustainable innovation as cost and not investment for future. de Jesus and Mendonça (2018), in their study on pathway to circular economy through sustainability innovation, studied the barriers that hamper this transition to sustainability. They classified those barriers into two major categories i.e. 'Hard' and 'Soft' barriers, where 'Hard' barriers include, inappropriate technology for sustainable innovation activities, gap between design of technology and diffusion of technology, and lack of training related to sustainability. Among the 'Soft' barriers are large financial support and investment for sustainability activities, high initial investment, inappropriate and lack of information for

economic transactions and decision making, improper framework for implementing sustainability, and resistance from customers regarding sustainable and innovative products. Greenland et al. (2018) conducted a study on sustainability innovation barriers adoption for food production and drip irrigation focusing on some regions of Australia. They found out that there is complex interrelationship among internal and external barriers. Major barriers included, costs associated with sustainability innovation, characteristics of users to determine the suitability of sustainability innovation for them, and lack of government support. Gupta and Barua (2018b) in their study on barriers to green and sustainable innovation in the context of SMEs identified some barriers and classified them into seven main categories including, managerial, technological, resource related, financial, economical, and external partnership related barriers. They found that technological and resource related barriers along with financial and economic barriers are the most prominent barriers that hinders sustainable and green innovation in organizations. Kiefer et al. (2019) in their study on barriers of innovation for sustainability came across an interesting finding that internal barriers are often given less importance than external barriers and most of the studies focus on external barriers. In their study on Spanish SMEs, they found that cooperation within the organization, organizational learning, an ISO ecological certification, and technological path dependency are major barriers to sustainability innovation. Arranz et al. (2019) conducted a study on Spanish organizations, the major finding of their study is that the complexity of the innovation process hinders the adoption of sustainability innovation practices in organizations. Other hindering factors include the uncertainty of the processes associated with innovation, and uncertainty of the market to accept sustainability innovation. They also found that public funding, collaborations agreements and information sourcing about green

technologies can help in facilitating the adoption of sustainability innovation within organizations.

2.4.   Research gaps and highlights

The above literature reviewed clearly reveals that there exist some attempts to investigate the barriers to sustainable innovation. For example, some studies have investigated the factors (barriers) that hinder the successful organizational social innovation (see e.g. Chalmers, 2013) and some have focused on barriers to supply chain innovation (see e.g. Böhme et al., 2014). Others have also attempted to investigate barriers to sustainable supply chains (see e.g. Al Zaabi et al., 2013) and barriers to sustainable innovation (see e.g. Laukkanen and Patala, 2014; de Jesus Pacheco et al. (2018); Gupta and Barua (2018)). de Jesus Pacheco et al. (2018) conducted literature review and discussion with experts to identify key barriers for green and eco-innovations for SMEs in Brazil. Their study identified only ten barriers for eco-innovation . Gupta and Barua (2018) carried out a study to identify barriers to manufacturing SMEs operations in India. Their barriers although exhaustive (36 barriers), mainly focused on green innovation without considering social barriers to innovation and large organizations. Similarly, Kiefer et al. (2019) conducted a study on Spanish SMEs and identified some barriers to environmental innovation. Their study also did not consider a comprehensive list of barriers but focused on only green innovation in the context of SMEs. Arranz et al. (2019) conducted a study focusing on barriers to green innovations on Spanish manufacturing and service organizations.

As indicted in the above discussion, most of the studies focused on barriers to green/eco-innovation without either considering social barriers or providing strategies to overcoming the barriers to sustainable innovations in their supply chains. The focus of many of the studies is on SMEs, given relatively no attention to large-scale organizations. Thus, most of the

previous studies on barriers to supply chain sustainability innovation have focused on SMEs and a mix of service and manufacturing organizations and also failed to provide strategies to deal with the barriers. Large-scale manufacturing organisations are very important when it comes to environmental degradation (Sarkis et al., 2011; Zhu and Sarkis, 2004) and are supposed to be given serious attention especially in relation to strategies for overcoming the barriers to sustainable innovations in their supply chain. Although few studies have investigated the barriers to green/eco/sustainable innovation of supply chains, none of these studies have moved a step further to identify the strategies for overcoming these barriers. These strategies are specific action plans to help manufacturing organisations and their supply chains to address the challenges to the realising supply chain sustainability innovation. More specifically, studies that have identified and prioritised barriers for guiding managers in determining the most severe barriers that need urgent attention and those that can be delayed and identified and prioritised some overcoming strategies to systematically deal with these barriers remain scarce. This study is therefore warranted and motivated by the fact that, there is lack of studies that comprehensively identifies the barriers and overcoming strategies to deal with the barriers to sustainable innovations of large-scale manufacturing organisations setting from emerging economies. Large-scale manufacturing organizations from emerging economies contribute significantly to the economy of those nations but also greatly to the growing global sustainability issue (Kusi-Sarpong et al., 2019a). For example, in India, large-scale manufacturing organisations contribute to about 20-25% of GDP and also are major contributors to environmental degradation (Kusi-Sarpong et al., 2019a; Sarkis et al., 2011). The steel sector in India alone contributes to 55% of environmental impact through the release of particulate matter into air. The automobile sector which is the second largest manufacturing sector in India, contributes significantly to environmental degradation (IBEF,

2019; Planning commission, 2018). Focusing on this sector by investigating the barriers and strategies for overcoming the barriers to sustainable innovation is one way of advancing sustainable development agenda from emerging economies (Kusi-Sarpong and Sarkis, 2019).

Therefore, this study identifies and evaluates a comprehensive framework of barriers and overcoming strategies for manufacturing supply chain sustainable innovation aided by a multi-criteria decision-making method, the Best-Worse Method (BWM) in some selected Indian manufacturing companies.

3. Methodology

This study applies a two-phase multi-case methodology to identify barriers and overcoming strategies to supply chain sustainability innovation. The first phase uses a combination of extensive literature review and modified-Delphi method to identify both barriers and overcoming strategies to sustainability innovation in supply chains. The second phase involves the application of Best Worst Method (BWM) (Rezaei, 2015; 2016) to evaluate and rank the barriers and overcoming strategies. The barriers are ranked based on their weights and the overcoming barrier strategies use a combination of these weights and the score of each strategy for ranking. BWM developed by Rezaei (2015; 2016) is one the most popular and efficient multi-criteria decision-analysis (MCDA) techniques used for obtaining criteria weights. BWM has the advantage over other mostly used MCDA techniques such as AHP and that it requires relatively lesser number of pairwise comparisons for the same number of criteria with a more consistent result. BWM has seen successful applications in various fields in recent time, some of which include Gupta and Barua (2016) for ranking enablers of innovation; Rezaei et al. (2016) for green supplier selection and evaluation; van de Kaa et al. (2017) for selection of biomass conversion technology; Gupta and Barua (2018) for supplier selection on the basis of innovation ability; Salami and Rezaei (2018) for

evaluating firms on the basis of their R&D performance; Rezaei et al. (2018a) for quality assessment of airport baggage handling; Rezaei et al. (2018b) for logistics performance index indicators; Kheybari et al. (2019) for bioethanol facility location selection; Wang et al. (2019) for identification and analysis of energy related risks; Kumar et al. (2020) for evaluating green performance of airports; Moktadir et al. (2018a) for assessing the challenges for implementing industry 4.0; Moktadir et al. (2019) for energy efficient supply chains; Munny et al. (2019) for social sustainability; Orji et al. (2019a) for evaluating critical success factors of using social media for supply chain social sustainability; Orji et al. (2019b) for evaluating the challenges to freight logistics eco-innovation; Suhi et al. (2019) environmental impact assessment; among others. The steps for BWM as given by Rezaei (2015; 2016) are explained below (the first 4 steps are conducted by the decision-makers/experts):

Step 1: Identify a relevant list of criteria.

Step 2: Choose best (B) and worst (W) criteria for main and sub-criteria.

Step 3: Using a scale of 1 to 9, ask each of the managers (experts) to elicit pairwise comparison between best criterion B over all the other criteria. This will result in vector $A_B = (a_{B1}, a_{B2}, \dots, a_{Bn})$.

Step 4: Similar to the above, each of the managers was asked to elicit pairwise comparison ratings of all the other criteria with worst criterion (W). This will also result in vector $A_w = (a_{1w}, a_{2w}, \dots, a_{nw})^T$.

Step 5: Next is to obtain the optimized weights (w_1^*, w_2^*, …, w_n^*) for all the criteria.
That is, we obtain the weights of criteria so that the maximum absolute differences for all j can be minimized for $\{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_W|\}$. The following minimax model will be obtained:

min max $\{|w_B - a_{Bj}w_j|, |w_j - a_{jW}w_W|\}$,

s.t.$\sum_j w_j = 1$,

$w_j \geq 0$, for all j . (1)

Model (1) is transformed to a linear model and is shown as:

$\min \xi^L$,

s.t.

$\left| w_B - a_{Bj} w_j \right| \leq \xi^L$, for all j,

$\left| w_j - a_{jW} w_W \right| \leq \xi^L$, for all j,

$\sum_j w_j = 1$,

$w_j \geq 0$, for all j. (2)

Model (2) can be solved to obtain optimal weights $(w_1^*, w_2^*, \ldots, w_n^*)$ and optimal value ξ^L.

Consistency (ξ^L) of attribute comparisons close to "0" is desired (Rezaei, 2016).

Once the global weights of each criterion is obtained by multiplying the local weights of both main- and sub- criteria, the next step is to compute the overall score of alternatives using the additive value function (Keeney and Raiffa, 1976) (3):

$V_i = \sum_{j=1}^n w_j u_{ij}$ (3)

where i is the index of any alternative, u_{ij} is the normalized score of alternative i with respect to criterion j. The value of u_{ij} can be obtained using expressions (4) and (5), where expression (4) is used for positive criteria (for benefit criteria/ whose criteria values we want to increase) and expression (5) is used for negative criteria (for cost criteria/whose criteria values we want to decrease).

$u_{ij} = \dfrac{x_{ij}}{\sum_j x_{ij}}$, for all i, (4)

$u_{ij} = \dfrac{\frac{1}{x_{ij}}}{\sum_j \frac{1}{x_{ij}}}$, for all i, (5)

where, x_{ij} is the actual score of alternative i with respect to criterion j.

4. Case study and results

4.1 *Case companies' information and experts' background*

For the purpose of achieving the objectives, eight experts from eight different manufacturing organizations were selected. The experts involved in the study have different

profiles, different levels of experience (minimum of 10 years' experience) and are from different organizations and were purposely selected from diverse backgrounds for the sake of achieving homogeneity to ensure that the results are more generalizable for the industry and to another industrial context. The details about these eight experts are mentioned in Table 1:

Table 1 Details about experts and case companies

Expert	Expertise	Experience (Years)	Educational Background	Organization
Expert 1	Senior Manger Purchase/ Procurement	12	MBA	Steel Manufacturing
Expert 2	Manager Production	10	B.Tech	Automobile Company
Expert 3	Manager Supply Chain	13	B.Tech	Automobile Company
Expert 4	Deputy Manager Production	10	B.Tech	Plastic Manufacturing
Expert 5	Manager Production Planning and Control	12	B.Tech	Steel Manufacturing
Expert 6	Senior Manager Human Resource & Interpersonal Skills	14	Ph.D.	Automobile Company
Expert 7	Senior Manager Marketing	12	MBA	Steel Manufacturing
Expert 8	Deputy General Manager	15	MBA	Electronic Manufacturing

4.2 *Barrier identification and finalization for supply chain sustainability innovation*

This phase involved finalization and categorization of barriers identified through literature review. After extensive literature review, a list of 37 potential barriers were identified and tabulated (see Table A8 of Appendix) and based on a three-round modified-Delphi approach, industrial experts from Indian manufacturing companies aided in the refinement and development of the barriers. Instead of starting with an open question on what might be most important to the subject under consideration (Seuring and Müller, 2008b) to create individual models by the experts and then, are combined, averaged and analysed to draw a final conclusion as in the Delphi method, the modified-Delphi method, allows experts to work independently but on the same model until that model can be accepted without major additional modifications (Paul, 2008). That is, whilst the Delphi method records multiple

mental models and tries to draw conclusions from the results by analysing statistical characteristics, the modified-Delphi method proposes a single mental model that is then modified until a consensus is met otherwise as pointed out by Fernández-Viñé et al. (2010), the discrepancies are dealt with using geometric mean aggregation and selection of the most influential experts answers using a threshold. In this study, a three-round modified-Delphi method that uses the same set of experts within each round was employed to help refine, focus and develop (practical validation (see Theißen and Spinler, 2014) the barriers. Since consensus was not met during the second round of review, we decided to ask the experts to vote during the third round on each of the barriers indicating a "Yes/Acceptance" and "No/Rejection" and then collated the number of "Yes/Acceptance" and selected the most influential experts answers using a threshold of 5 "Yes". This analysis can be found in Table A8 of Appendix.

This methodology resulted in a final set of barrier listing categorized into six main barriers and thirty-three sub-barriers. The final list of 6 main- and 33 sub-barriers is presented in Table 2.

Table 2 Barriers to sustainable supply chain innovation

Main Category Barrier	Sub-Category Barrier	Description	Supporting Literature
Technological Barriers (TH)	Lack of technology to facilitate resource optimization (TH1)	Organizations lack technologies related to waste management, recycling and reuse so that the resources can be utilized optimally and effectively.	Al Zaabi et al., 2013; Stewart et al., 2016; Movahedipour et al., 2017; AlSanad, 2018; De Jesus and Mendonça, 2018
	Lack of technical expertise and training (TH2)	The organizations lack technical know-how and right human resources to implement the intervention needed for sustainable innovation.	Al Zaabi et al., 2013; Stewart et al., 2016; Bhanot et al., 2017; De Jesus and Mendonça, 2018; Narayanan et al., 2018; Neri et al., 2018

	Gap between design and implementation of technologies (TH3)	Organizations often commit substantial resources in designing the green products but lack in framework for implementation of such technologies.	De Jesus and Mendonça, 2018
	Lack of R&D and innovation capabilities (TH4)	Organizations have very limited workforce and facilities that are enough to carry out sustainability related innovation activities.	Stewart et al., 2016; Gupta and Barua, 2018
	Lack of waste management and recycling facilities (TH5)	Organizations don't have recycling and waste management facilities at their end for optimum utilization of resources and reducing waste.	AlSanad, 2018; Gupta and Barua, 2018; Moktadir et al., 2018a,b; Narayanan et al., 2018
Economic and Financial Barriers (EF)	Lack of capital to carry out innovation activities (EF1)	Organization doesn't have enough capital to implement in technology and technical know-how required for carrying out sustainability related innovation activities.	Al Zaabi et al., 2013; Stewart et al., 2016; Bhanot et al., 2017; Movahedipour et al., 2017; De Jesus and Mendonça, 2018; Delmonico et al., 2018; Neri et al., 2018
	High transaction costs (EF2)	It refers to high cost of buying and selling the technologies required for sustainable innovation and might include communication costs, legal fees all of which deter innovation.	Bhanot et al., 2017; Chan et al., 2018; De Jesus and Mendonça, 2018; Jansson and Carlberg, 2019
	High initial investment in latest technology (EF3)	High cost of implementation, viz. investment in latest equipment and technologies, impedes the organizations to implement sustainability innovations.	Stewart et al., 2016; De Jesus and Mendonça, 2018; Neri et al., 2018; Majumdar and Sinha, 2019
	Uncertainty about return on investment (EF4)	Investments related to technology up gradation are riskier as the return on these investments is uncertain. This impedes the organizations in investing in sustainability related technology up gradations.	Stewart et al., 2016; Chan et al., 2018; De Jesus and Mendonça, 2018; Narayanan et al., 2018; Neri et al., 2018
Regulatory and Institutional Barriers (RI)	Inadequate institutional framework (RI1)	An institutional framework is precondition for successful implementation of sustainability program. Developing countries lack in proper institutional framework for sustainability.	Al Zaabi et al., 2013; AlSanad, 2018; De Jesus and Mendonça, 2018; Delmonico et al., 2018; Durdyev et al., 2018; Greenland et al., 2018
	Lack of incentives (RI2)	Inability of the government and regulatory bodies to provide incentives in terms of reduced tax slabs or subsidized technological assistance.	Stewart et al., 2016; Chan et al., 2018; De Jesus and Mendonça, 2018; Delmonico et al., 2018; Greenland et

			al., 2018; Narayanan et al., 2018
	Lack of pressure and non-conducive legal system (RI3)	Regulatory bodies fail to create necessary pressure on organizations to carry out sustainable activities.	AlSanad, 2018; De Jesus and Mendonça, 2018; Moktadir et al., 2018a
	Multiple, complex and changing regulations (RI4)	Developing countries have no set fixed rules and regulations. Regulations related to sustainability keeps on changing regularly and are often very complex for organizations to understand and implement.	Stewart et al., 2016; Narayanan et al., 2018; Majumdar and Sinha, 2019
	Red tape and lengthy documentation process (RI5)	Clearance regarding implementation of new technologies is very complex and takes a lot of time.	AlSanad, 2018; Durdyev et al., 2018
Social and Cultural Barriers (SC)	Perception that sustainable products are of low quality (SC1)	Consumers often believe that sustainable products are of lower quality because they use recycled materials and are sometimes reused.	Delmonico et al., 2018; Narayanan et al., 2018
	Fear of extra workload and loss of flexibility (SC2)	Employees of the organizations fear incorporating sustainability related innovations will cause them to loose flexibility in the organizations and will add extra workload.	Stewart et al., 2016
	Lack of entrepreneurial skills and out of box thinking (SC3)	Owners of the manufacturing organizations lack innovating thinking and skills to think differently and adapt sustainability innovations.	Stewart et al., 2016
	Negative attitudes towards sustainability concepts (SC4)	Lack of knowledge about benefits of sustainability leads to resistance towards implementation of sustainability.	Bhanot et al., 2017; Greenland et al., 2018; Narayanan et al., 2018
	Popularity of traditional technologies (SC5)	Traditional technologies for manufacturing and operations are sometimes so popular that people lack the acceptance of sustainable innovation and its benefits.	Durdyev et al., 2018; Greenland et al., 2018
Organizational Barriers (OG)	Lack of performance measurement and incentive systems (OG1)	Organizations do not have defined performance matrices to measure the sustainability related performance of the employees and hence fail to incentivize them for innovations.	Al Zaabi et al., 2013; Stewart et al., 2016; Bhanot et al., 2017
	Lack of functional integration and cooperation (OG2)	Inability of the various departments within the organisation to align their goals and work towards common goal of sustainable development.	Al Zaabi et al., 2013; Stewart et al., 2016; Delmonico et al., 2018
	Lack of clear responsibility and difficulty in decision making (OG3)	Responsibility to implement sustainability related change is not delegated properly and stakeholders are unclear of their role in the change or implementation.	Al Zaabi et al., 2013; Stewart et al., 2016
	Lack of decision making related to new innovations due to	In developing countries most of the manufacturing units are being managed by promoters who interfere in day to day	Expert Opinion

	controlling power of promoters (OG4)	working of managers thus limiting their abilities to innovate.	
	Lack of empowerment at lower level (OG5)	Lack of opportunity for lower level employees to be part of decision making and hence suggest/implement sustainability innovations.	Stewart et al., 2016; Neri et al., 2018
	Lack of top management commitment (OG6)	The top management is concerned mostly related to core business and lacks commitment to back activities related to sustainability innovation.	Al Zaabi et al., 2013; Bhanot et al., 2017; Movahedipour et al., 2017; Delmonico et al., 2018; Moktadir et al., 2018a; Neri et al., 2018
	Lack of communication (OG7)	Inability of the top management to management to communicate the sustainability goals and hence the need for sustainable innovation to lower level employees.	Neri et al., 2018
Market and Networking Barriers (MN)	Unclear customer requirements (MN1)	Customer requirements regarding what features they requires in products are not clear.	Stewart et al., 2016; Bhanot et al., 2017; AlSanad, 2018; Durdyev et al., 2018
	Lack of market demand (MN2)	Market requirements related to sustainable products is unclear and hence organizations are unwilling to put efforts for sustainability innovations.	Stewart et al., 2016; AlSanad, 2018; Chan et al., 2018; Narayanan et al., 2018
	Lack of understanding of customers (MN3)	Customers generally do not understand the benefit associated with adopting sustainable technologies and using sustainable products.	Stewart et al., 2016; AlSanad, 2018
	Lack of competitiveness (MN4)	Often there are no competitors in the market that adopt sustainable technologies and manufacture sustainable products thus impeding innovation efforts of the organizations.	Stewart et al., 2016
	Lack of ability to network with outsiders (MN5)	Organizations fail to collaborate with other organizations manufacturing similar products and thus fail to understand and share their technologies and benchmark them.	Stewart et al., 2016; Gupta and Barua, 2018
	Lack of trust in sharing information and forming joint ventures (MN6)	Organizations are unwilling to share information related to technologies used and changes implemented by them with other organizations thus hindering collaborations.	Stewart et al., 2016; Moktadir et al., 2018a,b; Neri et al., 2018
	Lack of sustainable suppliers (MN7)	Either there are no suppliers of sustainable products or the existing suppliers have lack of knowledge about sustainable products.	Delmonico et al., 2018; Durdyev et al., 2018; Moktadir et al., 2018a,b

4.3 Strategies for overcoming supply chain sustainability innovation barriers

Sustainability innovation although have magnum significance in the supply chains it is often married with numerous barriers as discussed in preceding sections. This therefore calls for the need to develop strategies to aid in overcoming these barriers. As the barriers are very critical and might require more than one strategy to completely overcome them, this study aims to propose a list all possible strategies to tackle and overcome these barriers. After review of literature and several rounds of discussion and deliberation with experts following the modified-Delphi approach, the study arrived with a final list of strategies for overcoming the barriers to sustainability innovation are as shown in Table 3.

Table 3 Strategies for overcoming sustainable supply chain barriers

Strategies	Description
Sustainable proficiencies and skill development strategy (ST1)	This strategy aims at creating an enabling environment for employees to develop green and sustainable competencies such as skills and know-how for aiding sustainable technologies and innovations idea generation to minimize environmental degradation.
Regulatory and environmental strategy (ST2)	This strategy aims at organization advocating for the formulation of various policies by the government to promote sustainability practices within the manufacturing organizations ecosystem. This can be in the form of tax cuts/holidays, access to latest green and sustainable technologies, infrastructural support, waste management and recycling policies and support for intellectual property development related to green and sustainable products and processes innovation.
Sustainable technology development strategy (ST3)	This strategy aims at organization developing technological competencies that can help in sustainable development via innovation. This includes acquiring latest technologies, developing recycling and reuse facilities within the organization.
Research and Development strategy (ST4)	This strategy aims at aiding the development of research facilities within the organization for developing and improving

		products and processes innovation. This includes setting up research labs for material reduction, energy management etc.					
Networking strategy (ST5)		This strategy aims at building collaborative capabilities and competencies within the organization and between external organizations and institutions. Collaboration can be in terms of technology exchange, joint training of employees, and joint development of new sustainable technology along with some R&D labs or institutions.					
Economic and incentives-based strategy (ST6)		This strategy aims at promoting the allocation of separate funds for sustainability innovation initiatives. This includes investment in technologies related to sustainability and providing financial incentives to employees for suggesting and implementing innovative ideas related to greening of the organizations.					
Marketing and promotion strategy (ST7)		This strategy aims at aiding marketing and promoting the benefits of sustainable products to the customers so that the demand of the products increases among customers as well as their acceptability for green and sustainable products.					

After the barriers and strategies are identified and finalized through literature review and series of discussions with experts, the next step is to rank the barriers. Following the BWM methodology, each of the experts was asked to individually identify the best and worst barriers among the main category as well as the sub-category barriers. The experts were further asked to rate best-to-others and others-to-worst for all the main and sub-category barriers respectively using 1 – 9 scale. The pairwise comparison for main category barriers for all eight experts is presented in Table 4.

Table 4 Pairwise comparison for Main category barriers

Best to Others for 8 respondents

Experts	Best Criterion	TH	EF	RI	SC	OG	MN
Expert 1	TH	1	2	5	4	6	9

Expert 2							
	SC	2	3	9	1	4	6
Expert 3							
	TH	1	4	5	2	9	7
Expert 4							
	EF	2	1	7	3	5	9
Expert 5							
	SC	2	4	7	1	6	9
Expert 6							
	TH	1	3	6	2	4	9
Expert 7							
	SC	2	4	8	1	9	6
Expert 8							
	TH	1	4	9	2	3	6

Others to Worst for 8 respondents

Experts ➡	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8
Worst Criterion ➡	MN	RI	OG	MN	MN	MN	OG	RI
TH	9	6	9	7	7	9	7	9
EF	6	6	3	9	3	6	3	4
RI	3	1	4	2	2	2	2	1
SC	4	9	7	5	9	7	9	7
OG	2	3	1	3	2	3	1	5
MN	1	2	2	1	1	1	2	2

The pairwise ratings for all the sub-category barriers are presented in Appendix A (Table A1-A6).

Next, using equation 2 and pairwise ratings obtained for all the main category barriers as well sub-category barriers, the weights of each of the main category and sub-category barriers are calculated. The detailed weights as well as the rankings for sub-category barriers are presented in Table 5.

Table 5 Criteria weights and rankings of the barriers

Main Criteria	Main Criteria Weight	Sub Criteria	Sub Criteria Local Weights	Sub Criteria Global Weights	Ranks

Technological (TH)	0.325	TH1	0.081	0.026	11
		TH2	0.354	0.115	1
		TH3	0.072	0.023	14
		TH4	0.291	0.094	2
		TH5	0.203	0.066	6
Economical and Financial (EF)	0.180	EF1	0.138	0.025	12
		EF2	0.089	0.016	19
		EF3	0.469	0.084	4
		EF4	0.304	0.055	7
Regulatory and Institutional (RI)	0.068	RI1	0.195	0.013	21
		RI2	0.288	0.020	16
		RI3	0.358	0.024	13
		RI4	0.080	0.005	31
		RI5	0.079	0.005	32
Social and Cultural (SC)	0.280	SC1	0.170	0.048	8
		SC2	0.279	0.078	5
		SC3	0.129	0.036	9
		SC4	0.096	0.027	10
		SC5	0.327	0.092	3
Organizational (OG)	0.089	OG1	0.216	0.019	17
		OG2	0.075	0.007	27
		OG3	0.063	0.006	30
		OG4	0.211	0.019	18
		OG5	0.101	0.009	24
		OG6	0.223	0.020	15
		OG7	0.110	0.010	23
Market and Networking (MN)	0.058	MN1	0.081	0.005	33
		MN2	0.119	0.007	26
		MN3	0.098	0.006	29
		MN4	0.259	0.015	20
		MN5	0.102	0.006	28
		MN6	0.146	0.008	25
		MN7	0.195	0.011	22

The global weight for each sub-criterion in Table 5 is calculated by multiplying the local weight of that sub-criterion by the weight of its parent main criterion. Once the sub-category barrier weights are obtained, next step is to identify which strategies are helpful to overcome these barriers. All of the seven strategies were analysed with respect to each of the main category barriers first and also for sub-category barriers. Each of the experts was first asked to rate each strategy with respect to main category barriers using 1 – 9 Likert scale (see Table A7 in

Appendix for rating of strategies with respect to main category barriers by expert 1), where 1 means very low and 9 means very high. Average of all the experts was taken and using equation (4), the normalized value of the scores, u_{ij} is obtained. This normalized value u_{ij} is than multiplied by individual weights of main criteria barriers to obtain V_i values for all the strategies using equation (3). These V_i values represent the ranking of strategies for main criteria barriers as shown in Table 6. Similarly, the rankings of strategies for all the individual sub-category barriers was done by following the above-mentioned steps. The collated values of V_i and corresponding ranks for each strategy with respect to main category and sub-category barriers are presented in Table 6.

Table 6 Ranking of strategies

Strategies	Main Category Barriers		Technological Barriers		Economic and Financial barrier		Regulatory and Institutional Barriers		Social and Cultural Barriers		Organizational Barriers		Market and Networking Barriers	
	V_i	Rank	V_i	Rank	V_i	Rank	V_i	Rank	V_i	Rank	V_i	Rank	V_i	Rank
ST1	0.146	5	0.055	3	0.018	6	0.007	5	0.042	2	0.014	2	0.008	4
ST2	0.151	2	0.041	6	0.022	5	0.021	1	0.035	5	0.012	4	0.008	5
ST3	0.149	3	0.057	1	0.016	7	0.007	6	0.042	4	0.013	3	0.008	3
ST4	0.148	4	0.042	5	0.023	4	0.006	7	0.034	6	0.012	6	0.007	7
ST5	0.134	6	0.051	4	0.029	2	0.008	3	0.027	7	0.012	5	0.010	1
ST6	0.162	1	0.056	2	0.045	1	0.012	2	0.042	3	0.016	1	0.008	6
ST7	0.110	7	0.022	7	0.027	3	0.007	4	0.058	1	0.010	7	0.009	2

5. Discussing the barriers and strategies

5.1 Discussion on the ranking of the barriers

This study identified and finalized the barriers to sustainable innovation and overcoming strategies to these barriers through a combination of literature review and several rounds of discussions (Modified-Delphi approach) with Indian manufacturing industrial experts. The barriers and strategies were then analysed in two separate phases, again using the same set of Indian manufacturing industry experts' inputs. In the first phase of analysis (See Table 5 for

this results), "Technological barriers" (TH) was found to be most pressing issue confronted by Indian manufacturing industry for adopting and implementing supply chain sustainability innovation. Technological support is one of the most essential elements for carrying out sustainability related innovations in the supply chains. This emphasizes the fact that, manufacturing organizations are lacking the technological know-how to support the implementation of sustainability-oriented innovation especially from an emerging and developing countries such as Indian (Gupta and Barua, 2017). These organizations are faced with very serious challenges of acquiring and developing technologies capability for, for example, waste management, recycling and reuse of materials and components (AlSanad, 2018; De Jesus and Mendonça, 2018). Lack of technological support can be overcome by carrying out innovative activities by these manufacturing organizations, yet these organizations lack the capacity for developing innovative capabilities partly due to lack of research and development facilities which hampers technological capabilities growth of these organizations (Gupta and Barua, 2018). The next pressing issue is the "Social and Cultural barriers" (SC), one of the three pillars of sustainability is the economic factors, indicating that the products should be environmentally friendly but also economic-focused. This sometimes leads to a perception among users that sustainable products are of lower quality and that the quality has been compromised to compensate for cost reduction, which leads to resistance among buyers for sustainable products (Narayanan et al., 2018). Resistance is not only external but also internal. For example, employees fear that incorporating sustainability related initiatives or activities might add extra workload to their regular schedule as well as fear that they do not have the necessary skill-sets to perform sustainability related tasks (Stewart et al., 2016). Third important/severe barrier to supply chain sustainability innovation implementation is "Economic and Financial" (EF) concerns. Mostly, firms spend capex on

building infrastructure and are often left with little or sometimes no money to implement innovative technologies for sustainable innovation in the manufacturing organizations (Neri et al., 2018). Acquiring latest technologies also require high/huge financial commitments, which include sometimes legal fees, consultancy fees and expenses related to experts, these costs further act as deterrent for organizations to move ahead with sustainability related activities (Chan et al., 2018; De Jesus and Mendonça, 2018).

Among the sub-category barriers, "Lack of technical expertise and training" (TH2) emerged as the most important issue related to supply chain sustainability innovation. Implementing sustainability related innovations is a challenging task and requires enough technical skill-sets. Manufacturing organizations often lack the technical know-how and expertise to carry out sustainable innovation related activities within the supply chains. Many a times either the right person for the particular task is not available or that person lacks sufficient skill sets and experience (Narayanan et al., 2018; Neri et al., 2018). This brings us back to the argument that there's the need for financial availability to help hire new staffs with the right skill-sets or train existing staffs to build the required competencies, whichever way is economically viable should be pursued. "Lack of R&D and innovation capabilities" (TH4) also emerges as an important barrier that needs attention. Related to the previous challenge of lack of skilled workforce, organizations also lack the research and development capabilities required to carry out innovations, develop new technologies or technological ideas, and processes for sustainable innovation and hence promoting sustainable development (Gupta and Barua, 2018). The third most challenging sub-barrier is "Popularity of traditional technologies" (SC5). The high ranking of the barrier tells us that, manufacturing organizations are seriously confronted with issues related to switching from traditional technologies use and, consumers feel more comfortable in using traditional products which hinders the

acceptance and willingness to adopt to latest technologies to aid in reducing negative impacts on environment (Greenland et al., 2018). However, "High initial investment in latest technology" (EF3) happens to be another important issue hampering supply chain sustainability innovation. Switching to processes that incorporate sustainability principles requires significant change in technology and thus requires huge amount of investment. This means that, Indian Manufacturing organizations are faced with the challenge of acquiring new technology which comes with an initial huge capital investment and acquisition cost, derailing the progress of sustainability innovation implementation (Neri et al., 2018; Majumdar and Sinha, 2019).

5.2 Discussion on the strategies

Analysis of strategies to overcome barriers to sustainability innovation (the second phase of the analysis) reveals that one strategy is not completely enough to overcome these barriers as is evident from closeness of the total weighted scores of each strategy with respect to the barriers (See Table 6 for this results). For overcoming the overall major barriers (main category barriers perspective), "Economic and incentives-based strategy" (ST6) emerges as the most important strategy for dealing with them. Technological barrier is the most prominent barrier among main barriers, and "economic and incentives-based strategy" (ST6) can be the most useful strategies for overcoming this barrier. Allocating separate funds for acquiring new technology and research facilities will strengthen the technology development and absorption capabilities of the organizations. Providing incentives to the employees for innovative thinking will also create a positive work culture and environment within the organizations and this will aid in reducing employee resistance for adopting sustainable technologies and drive out their fear, thus overcoming social and cultural barriers.

For overcoming technological barriers, the most important strategy emerges to be "sustainable technology development strategy" (ST3). Sustainable technologies for new product development and processing and facilities related to recycling and waste management facilities can help overcome this barrier. "Economic and incentives-based strategy" (ST6) is the second most important strategy for overcoming technological barriers, as funds are required for acquiring latest technologies to spur the sustainable technology related innovation in the organizations.

For overcoming "economic and financial barriers" (EF), economic and incentives-based strategy" (ST6) is most desirable and important according to the study and an obvious one. Building financial capability can enable organizations to have access to enough capital for investment in sustainability related innovation and technologies. Also "Networking strategy" (ST5) will be helpful for overcoming the economic barriers, as organizations can collaborate with other organizations for sharing of technology and resources and thus reducing the burden to invest heavily in these resources.

For overcoming "regulatory and institutional barriers" (RI), "regulatory and environmental strategy" (ST2) emerges as the most important strategy. Unfortunately, this barrier are external to the manufacturing organizations and so require working closely with the government to formulate environmental management policies and strictly enforcing them with necessary and proper support. As a part of the government policy on environmental management, some incentives such as monetary benefits in terms of tax cuts and financial incentives should be introduced. "Economic and incentives-based strategy" (ST6) emerges as the second most important strategy when dealing with "regulatory and institutional barriers" (RI). This means that should the government fails to provide monetary benefits and incentives as a part of their policies, the manufacturing organizations should step forward to overcome

these regulatory and institutional barriers by building up strong financial capabilities from within and thus can provide internal incentives.

For overcoming "Social and cultural barriers" (SC), "Marketing and promotion strategies" (ST7) is found to be most suitable strategy. Customers perceive sustainable products as of low quality due to recycling of materials and hence the customer demand for these products is slightly lesser (MacArthur, 2013). Also, popularity of traditional technologies often eclipses the benefits of sustainable products (Kirchherr, et al., 2018).To overcome these issues, promoting the benefits of sustainable products can be useful for creating demand in market. Sustainable proficiencies and skill development strategy (ST1) is another important strategy for overcoming "social and cultural barriers" (SC). By developing necessary proficiencies and skills related to sustainability among employees, manufacturing organizations can drive out the fear and negative attitudes from their minds.

For overcoming "organizational barriers" (OG), economic and incentives-based strategy (ST6) emerges as most important strategy. By providing incentives to the employees for innovations, these employees may be motivated to further innovative thinking and participation in the sustainable development process. Furthermore, the financial incentives can motivate top management to be more committed towards the adoption of sustainable practices in the organization. "Sustainable proficiencies and skill development strategy" (ST1) happens to be the second most important strategy for overcoming these organizational barriers. Having sustainable proficiencies and skills can help managers as well as employees to clearly make decisions related to new innovations and technology changes and also empower them to think out of the box.

For overcoming "market and networking related barriers" (MN), "Networking strategy" (ST5) emerges as the most important strategy. This means that, by collaborating with other

organizations, manufacturing organizations can share information, technology and even train their employees in other manufacturing organizations. Second important strategy for overcoming the "market and networking related barriers" (MN) is "Marketing and promotion strategy" (ST7). Thus, by promoting the benefits of sustainable products, manufacturing organizations can overcome the current lack of market demand for these products and help customer understand the benefits of these products, thus increasing the competitiveness in the market.

6. Implications of the study

This study has some major implications for manufacturing sector, managers as well as academicians. Manufacturing sector is always in news whenever policy makers and researchers discuss about the environmental degradation due to their massive negative contribution to the environment. Manufacturing sector needs to adopt and invent sustainable solutions to environmental issues arising because of their activities. But given their size and complexity of the processes, manufacturing organizations face numerous barriers in implementing innovative solutions. The present study provides a framework to manufacturing organisations to work on overcoming these barriers. This study identifies thirty-three barriers to sustainable supply chain innovations in the context of manufacturing industries of a developing economy. Manufacturing organizations can work on these identified barriers in order to become sustainable innovative. This study identifies 'Lack of technical expertise and training', 'Lack of R&D and innovation capabilities' and 'Popularity of traditional technologies' as major barriers hindering sustainable supply chain innovations. Managers and organizations can devise special training workshops and programs in order to enhance technical skills and capabilities of their employees. This research can also help

managers to focus more on developing research facilities at their organizations so that employees are able to carry out innovative activities.

The policy makers and regulatory authorities of the developing countries can also benefit from this research in a way that they can test the current framework in different manufacturing industries in order to further understand the prevailing barriers. The policy makers can also focus on capacity building for manufacturing sector through technology absorption support and skill enhancement trainings for the employees of manufacturing sector.

This study also identifies and ranks strategies to overcome these barriers. This study provides an in-depth analysis of strategies for each category barriers individually and thus organizations can be more beneficial by implementing separate strategies for each category barriers. At the macro level, this study provides findings that managers and also regulatory bodies should strategies to infuse more money into research activities as well as technological capability building activities in order to be more innovative in sustainable development. Government should also take cue from the findings to provide better tax structures and incentives to organizations working towards sustainable development.

7. Conclusion and future research

7.1. Conclusion

Sustainability is a global pressing concern. The manufacturing industry is one of the industries that contribute greatly to the growing global sustainability issue (Kusi-Sarpong et al., 2019a). Addressing this complex and growing global sustainability issue requires the manufacturing companies to develop innovative strategies to deal with them. However, manufacturing companies especially those in the emerging economies such as India are faced with many barriers, some of which are technological, some are organizational, when

attempting to innovate for sustainability. To deal with this issue, the barriers that hinders the adoption and implementation of sustainable innovation in the manufacturing industry should be properly identified, evaluated and ranked to provide some idea on how to strategize and approach these barriers based on their severities. Overcoming these barriers require some strategies aligned to the barriers. There is no single strategy that can help overcome all the barriers. For current case of an emerging economy, technological, cultural and social and economic barriers are most prominent which needs urgent attention by organizations and policy makers. To overcome these barriers, several strategies can work, like investment in latest technologies and motivating employees through some incentives for thinking out of the box and adopting sustainable practices within the organization. In addition, regulatory support is also very essential in the form of supportive policies and minimal tax slabs for organizations adopting green and sustainable practices. Support can also be in the form of providing access to infrastructure and technologies available with other developed countries and also training organizations to inculcate the culture of sustainability among them.

This study identifies a list of barriers that hinders adoption, implementation and upscaling of sustainable supply chain innovation in the manufacturing industry. It further proposes overcoming strategies that seek to aid management decision to dealing with these barriers systematically. This study therefore contributes to three streams of literature, namely sustainability, supply chain management, and innovation management and in an integrated manner. It extends previous studies that only focus on the implementation of sustainable supply chain innovation management to considering the hinderances that firm may be confronted with when seeking to innovate for supply chain sustainability and providing overcoming strategies for dealing with these hinderances, paving the way for smooth adopting, implementing and upscaling.

7.2. Limitations and future scope

As is the case with any other study, this study also has some limitations. This study is based on certain barriers to sustainability innovation in supply chains, but there are few barriers related to social aspects. Future studies can specifically include social barriers to sustainability innovation of supply chains. This study also arrived with thirty-three barriers and categorized into six based on modified-Delphi approach; future studies can further explore these barriers using a broader interview. The study specifically uses MCDM technique to evaluate and rank the barriers and select the optimal strategies, future studies can include using techniques such as SEM (structure equation modelling) for determining the relationship among barriers and statistically testing the model (framework of barriers) using a larger data set as this study's technique only used a few experts for concluding the results. The results are also limited to few case companies, and that future studies can include more case companies and from different fields of manufacturing or even service industries. Clearly, this initial study aids in opening more opportunities for further works to be conducted.

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Appendix A

Table A1. Pairwise comparison for Technological barriers

Best to Others for 8 respondents

Experts	Best Criterion	TH1	TH2	TH3	TH4	TH5
Expert 1	TH2	4	1	9	3	5
Expert 2	TH4	9	3	7	1	4
Expert 3	TH2	9	1	6	3	2
Expert 4	TH2	6	1	9	3	5
Expert 5	TH4	3	4	9	1	2
Expert 6	TH5	9	3	6	4	1
Expert 7	TH4	9	2	7	1	4
Expert 8	TH2	9	1	7	3	6

Others to Worst for 8 respondents

Experts →	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8
Worst Criterion →	TH3	TH1	TH1	TH3	TH3	TH1	TH1	TH1
TH1	4	1	1	2	6	1	1	1
TH2	9	6	9	9	2	6	7	9
TH3	1	2	2	1	1	2	2	2
TH4	3	9	4	5	9	3	9	6
TH5	2	3	6	2	5	9	3	2

Table A2. Pairwise comparison for Economic and Financial barriers

Best to Others for 8 respondents

Experts	Best Criterion	EF1	EF2	EF3	EF4
Expert 1	EF3	3	8	1	5
Expert 2	EF3	5	4	1	8
Expert 3	EF4	9	5	3	1
Expert 4	EF4	5	9	2	1
Expert 5	EF3	8	6	1	4
Expert 6	EF3	4	9	1	3
Expert 7	EF4	5	9	3	1
Expert 8	EF3	3	9	1	5

Others to Worst for 8 respondents

Experts →	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8
Worst Criterion →	EF2	EF4	EF1	EF2	EF1	EF2	EF2	EF2
EF1	5	2	1	3	1	4	3	4
EF2	1	3	2	1	2	1	1	1
EF3	8	8	6	6	8	9	4	9
EF4	2	1	9	9	3	3	9	2

Table A3. Pairwise comparison for Regulatory and Institutional barriers

Best to Others for 8 respondents

Experts	Best Criterion	RI1	RI2	RI3	RI4	RI5
Expert 1	RI3	3	4	1	6	9
Expert 2	RI2	5	1	3	4	9
Expert 3	RI2	2	1	6	5	9
Expert 4	RI1	1	7	2	9	4
Expert 5	RI3	4	5	1	9	6
Expert 6	RI2	5	1	3	9	7
Expert 7	RI3	9	4	1	7	8
Expert 8	RI3	3	2	1	9	6

Others to Worst for 8 respondents

Experts ➡	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8
Worst Criterion ➡	RI5	RI5	RI5	RI4	RI4	RI4	RI1	RI4
RI1	5	2	7	9	4	3	1	5
RI2	3	9	9	2	3	9	3	6
RI3	9	4	2	6	9	4	9	9
RI4	2	3	3	1	1	1	2	1
RI5	1	1	1	3	2	2	2	2

Table A4. Pairwise comparison for Social and Cultural barriers

Best to Others for 8 respondents

Experts	Best Criterion	SC1	SC2	SC3	SC4	SC5
Expert 1	SC5	5	2	9	6	1
Expert 2	SC2	6	1	9	4	3
Expert 3	SC2	4	1	7	9	3
Expert 4	SC5	7	3	5	9	1
Expert 5	SC3	5	4	1	3	9
Expert 6	SC5	3	2	6	9	1
Expert 7	SC1	1	4	7	9	3
Expert 8	SC5	5	3	9	4	1

Others to Worst for 8 respondents

Experts →	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8
Worst Criterion →	SC3	SC3	SC4	SC4	SC5	SC4	SC4	SC3
SC1	3	2	3	2	2	5	9	3
SC2	6	9	9	4	3	7	3	4
SC3	1	1	2	3	9	2	2	1
SC4	2	3	1	1	4	1	1	5
SC5	9	5	5	9	1	9	4	9

Table A5. Pairwise comparison for Organizational barriers

Best to Others for 8 respondents

Experts	Best Criterion	OG1	OG2	OG3	OG4	OG5	OG6	OG7
Expert 1	OG6	4	9	6	2	3	1	5
Expert 2	OG4	2	7	9	1	5	3	6
Expert 3	OG4	4	5	7	1	3	6	9
Expert 4	OG1	1	4	9	3	2	5	7
Expert 5	OG1	1	3	6	4	9	5	7
Expert 6	OG6	4	7	6	3	9	1	5
Expert 7	OG7	3	9	7	4	6	2	1
Expert 8	OG6	2	9	6	3	7	1	5

Others to Worst for 8 respondents

Experts ➡	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8
Worst Criterion ➡	OG2	OG3	OG7	OG3	OG5	OG5	OG2	OG2
OG1	3	7	3	9	9	3	6	7
OG2	1	2	3	3	5	2	1	1
OG3	2	1	2	1	2	2	2	2
OG4	6	9	9	5	3	6	3	6
OG5	5	3	5	7	1	1	2	2
OG6	9	6	2	3	3	9	7	9
OG7	3	2	1	2	2	4	9	3

Table A6. Pairwise comparison for Market and Networking barriers

Best to Others for 8 respondents

Experts	Best Criterion	MN1	MN2	MN3	Mn4	MN5	MN6	MN7
Expert 1	MN7	9	7	4	3	6	5	1
Expert 2	MN4	5	6	2	1	9	4	3
Expert 3	MN4	9	4	5	1	6	2	6
Expert 4	MN6	5	3	9	4	6	1	4
Expert 5	MN5	6	2	9	5	1	7	4
Expert 6	MN4	4	6	7	1	9	3	5
Expert 7	MN7	7	3	4	5	9	6	1
Expert 8	MN4	4	6	5	1	7	9	3

Others to Worst for 8 respondents

Experts ➡	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8
Worst Criterion ➡	MN1	MN5	MN1	MN3	MN3	MN5	MN5	MN6
IN1	1	4	1	3	3	4	2	4
IN2	2	2	3	6	7	3	6	3
IN3	3	7	3	1	1	2	5	3
IN4	4	9	9	3	3	9	3	9
IN5	2	1	2	2	9	1	1	2
IN6	3	3	7	9	2	5	2	1
IN7	9	5	2	4	4	3	9	6

Table A7 Rating of Expert 1 for each strategy with respect to all main category barriers

	TH	EF	RI	SC	OG	MN
ST1	8	4	3	5	6	7
ST2	6	6	9	4	5	3
ST3	9	2	4	4	7	6
ST4	7	4	3	6	7	2
ST5	7	6	2	3	5	7
ST6	7	8	7	3	5	7
ST7	2	3	2	5	6	9

Table A8 Potential list of barriers to sustainable supply chain innovation

Barriers	Average Responses	Accept/Reject
Lack of technology to facilitate resource optimization	7	Accept
Lack of technical expertise and training	7	Accept
High transaction costs	6	Accept
Lack of support from owners and chairman of family controlled organizations	2	Reject
Lack of R&D and innovation capabilities	7	Accept
Gap between design and implementation of technologies	6	Accept
Perception that sustainable products are of low quality	8	Accept
Lack of waste management and recycling facilities	8	Accept
Lack of capital to carry out innovation activities	8	Accept
Stringent policies and bureaucratic hurdles	3	Reject
High initial investment in latest technology	8	Accept
Uncertainty about return on investment	6	Accept
Political instability	2	Reject
Lack of incentives	6	Accept
Lack of pressure and non-conducive legal system	7	Accept
Multiple, complex and changing regulations	7	Accept
Red tape and lengthy documentation process	7	Accept
Uncertain future	1	Reject
Fear of extra workload and loss of flexibility	7	Accept
Lack of entrepreneurial skills and out of box thinking	7	Accept
Negative attitudes towards sustainability concepts	7	Accept
Popularity of traditional technologies	6	Accept
Lack of performance measurement and incentive systems	6	Accept
Lack of functional integration and cooperation	5	Accept
Lack of clear responsibility and difficulty in decision making	7	Accept
Lack of sustainable suppliers	7	Accept
Lack of competitiveness	6	Accept
Lack of decision making related to new innovations due to controlling power of promoters	6	Accept
Lack of empowerment at lower level	5	Accept
Lack of ability to network with outsiders	7	Accept
Lack of market demand	7	Accept
Lack of top management commitment	8	Accept
Lack of communication	7	Accept
Unclear customer requirements	7	Accept
Inadequate institutional framework	6	Accept
Lack of understanding of customers	7	Accept
Lack of trust in sharing information and forming joint ventures	6	Accept