An integrated approach to explore the barriers to lean manufacturing in the context of the COVID-19 pandemic: implications for sustainability

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Abstract

Purpose – The apparel industry of Bangladesh is rethinking lean manufacturing (LM) deployment because of the challenges imposed by the COVID-19 pandemic. Due to COVID-19, LM implementation in the apparel industry has become more difficult. Thus, the purpose of this study is to explore the barriers to implementing LM practices in the apparel industry of Bangladesh in the context of COVID-19 pandemic.

Design/methodology/approach – For evaluating the barriers, an integrated framework that combines the Delphi method and fuzzy total interpretive structural modeling (TISM) has been designed. The application of fuzzy TISM has resulted in a structured hierarchical relationship model of the barriers with driving and driven power.

Findings – The findings reveal that "lack of synchronization of lean planning with strategic planning", "lack of proper understanding of lean concept" and "low priority from the top management" are the three top most important barriers of LM implementation in apparel industry.

Practical implications – These findings will help the apparel industry to formulate strategy for implementing the LM practices successfully. The proposed model is expected to contribute to the sustainable development goals (SDGs) such as Responsible Consumption and Production (SDG 12);

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Decent Work and Economic Growth (SDG 8); Industry, Innovation and Infrastructure (SDG 9) via resilient strategies.

Originality/value – This study is one of few initial efforts to investigate LM implementation barriers during the COVID-19 epidemic in a real-world setting.

Keywords Apparel industry, COVID-19, Delphi method, Fuzzy TISM, Lean manufacturing (LM), Sustainability

Paper type Research paper

1. Introduction

There have been substantial impacts on individuals, businesses and economies because of a recently discovered coronavirus disease known as COVID-19 (Habibi *et al.*, 2022; Lim and To, 2022). This COVID-19 pandemic around the globe caused unexpected disruptions in industrialized processes (Mitra *et al.*, 2020; Nicola *et al.*, 2020). Also, the pandemic's impacts aligned with other events (e.g. war in Ukraine, energy crisis and climate issues) have deployed middle and long-term impacts on supply chains, leveraging more disruptions and generating inflation in the global scenario. Additionally, COVID-19 has presented a worst-case scenario affecting key stock availability: a sudden increase in demand paired with significant raw material shortages owing to global supply chain disruptions (Paul and Chowdhury, 2021). A disturbance in the supply chain network might potentially hinder vaccine development and distribution also (Hendricks *et al.*, 2013). Because of the pandemic, companies are being forced to rethink their strategic and operational initiatives, something they had not anticipated (Ivanov, 2020). However, the COVID-19 pandemic presents a unique set of problems like disruption in supply chain, less production, devastating economic shocks for diverse corporate entities for the companies of emerging economy like Bangladesh (Munim *et al.*, 2022; Pujawan and Bah, 2022; Sarker *et al.*, 2022; Tusher, 2022).

In the context of the social and economic development of Bangladesh, the apparel sector plays an essential role. This sector is the most significant and foreign earning export-oriented industry in Bangladesh that is now worth several billion dollars (Munim *et al.*, 2022; Tusher, 2022). Despite the remarkable contributions, Bangladesh's garment industry is beset by various challenges, such as poor production and efficiency, lengthy lead times and high quality expenses, and other difficulties during this pandemic situation (Hasan *et al.*, 2022). These issues at the apparel manufacturers' end ultimately expose overseas customers to an unreasonable level of risk and uncertainty. Moreover, the apparel industries are forced to reconsider their conventional manufacturing approach due to global competition and volatile market conditions (Bashar and Hasin, 2019; Tortorella *et al.*, 2021). In addition, it is not clear how lean manufacturing (LM) can deal with the pandemic impacts of organizational changes and their implications on organizations (Zhang *et al.*, 2020). The typical lean strategy, on the other hand, boosts efficiency, productivity, revenue and customer value while decreasing wastes including idle time, excess production and processing, transportation and defects (Debnath *et al.*, 2023). Because of the worldwide spread of the COVID-19 epidemic, the industrial sector is one of the most disrupted systems so companies in the manufacturing sector are seeking for solutions that will help them satisfy customer needs despite the current circumstances (Badhotiya *et al.*, 2022). Therefore, various lean strategies may be adopted to overcome such problems (Vasanthakumar *et al.*, 2016; Hasan *et al.*, 2022). International and national experts advise Bangladeshi garment firms to use lean approaches for sustainable growth and risk mitigation (Hasan *et al.*, 2022). However, most of the previous literature focus on the theoretical aspects of lean adoption rather than practical considerations (Narula *et al.*, 2021). It is also worth noting that no earlier research has assessed the challenges of implementing LM in the apparel industry, particularly in the disruptive setting of a pandemic like COVID-19. Despite the fact that companies are eager to apply LM practices to accelerate their industries faced with interruptions caused by the

COVID-19 epidemic, there are significant issues to overcome (Tortorella *et al.*, 2021). There arise several barriers and challenges to implement LM practices in the apparel sector of Bangladesh during the COVID-19 pandemic, whereas latest literature claim that no study has yet looked into the effects of barriers on the implementation of LM for effective production practices in this sector (Chaple *et al.*, 2018; Hasan *et al.*, 2022; Munim *et al.*, 2022; Rathi *et al.*, 2022). After analyzing the previous relevant literature, this study formulates an outline for exploring the barriers of adopting LM and tries to address the subsequent research questions (RQs):

RQ1. In light of the COVID-19 epidemic, what are the most potential barriers to the application of LM in Bangladesh's apparel industry?

RQ2. How can a decision support framework be designed to model and analyze the influential relationships among these barriers of adopting lean practices?

RQ3. How can the framework help industrial managers and LM professional in formulating effective strategies for implementing lean practices in the apparel industry?

Aiming to answer these *RQs*, the current study has theoretically advanced the existing knowledge base of LM by examining the barriers to LM in the context of COVID-19 pandemic. First, the existing literature has been reviewed to identify the barriers to LM. Then, a novel framework integrating the Delphi method and fuzzy total interpretive structural modeling (TISM) approach has been proposed for examining the barriers. The Delphi method has been used to identify the relevant barriers in the context of the apparel industry of Bangladesh. To examine the influential relationships among the barriers, a fuzzy TISM model has been proposed. This study has chosen the fuzzy TISM approach since it has the capability of mapping the barriers with influential relationships from the imprecise data. Regarding practical contributions, the findings of the study may aid apparel manufacturers in making decisions about developing distinctive lean implementations and transforming current systems into competitive ones. The Delphi-based fuzzy TISM model also helps industrial managers formulate effective strategies for the implementation of LM, which can facilitate to achieve sustainable development goals (SDGs) as well.

The article is set up as follows. Section 2 offers a comprehensive review of existing literature on LM practices and the difficulties in applying LM techniques in the context of the COVID-19 epidemic. In Section 3, the data collection process and the computational steps of the proposed Delphi and fuzzy TISM framework have been presented. The results of using the suggested framework are shown in Section 4 of the article. Section 5 discusses the significance of the results and the insights that emerged from the research. The study is concluded in Section 6 with a discussion of its shortcomings and areas for further investigation.

2. Literature review

2.1 Lean manufacturing practices in apparel sector during COVID-19

Lean manufacturing is a methodology consisting of a collection of management techniques and the acquisition of manufacturing operations that may be utilized to eliminate waste and minimize the uncertainty of suppliers, customers and internal resources and processes (Bashar *et al.*, 2021; Hasan *et al.*, 2022). However, the pandemic has had a negative effect on economic growth since most countries have spent less on capital projects to properly equip their health sector, reducing investments in other sectors (Béland *et al.*, 2020). The outbreak led to a modification in work practices intended at protecting the health of employees. Moreover, researchers are paying more attention to management techniques that promote continuous development of companies, such as LM in this pandemic time (Tortorella *et al.*, 2021). Investigations on LM have found benefits across a wide range of areas, including cost savings, better quality, shorter delivery times and increased employee performance (Piercy and Rich,

2009; Laureani and Antony, 2010; Carlborg *et al.*, 2013; Hadid and Mansouri, 2014; Ojasalo and Ojasalo, 2018; Cavdur *et al.*, 2019). In addition, lean concepts have made textile and clothing businesses more sustainable and competitive (George *et al.*, 2022). As a result, the anticipation of gaining these advantages, along with the need for firms to be more competitive, has encouraged industrial organizations all over the world to widely implement LM (Buer *et al.*, 2021).

Bangladesh's apparel industry is essential to the country's economic and social progress. After China, Bangladesh is currently the world's second-largest exporter of clothing (Khan and Ullah, 2017). After beginning its development in the 1970s, Bangladesh's apparel industry witnessed tremendous expansion, becoming the multibillion-dollar, export-focused business it is today. The total earning from the export of apparel goods in 1984–85 was 31.57mn USD (Bashar and Hasin, 2019). Although it may seem smooth sailing, the recent pandemic has hindered this growth severely. According to BGMEA, Bangladesh's apparel export in the calendar year of 2020 is 27.471bn USD, significantly lower than 33.073bn USD in the calendar year of 2019 (Swazan and Das, 2022). Also, this has been the lowest level of apparel export since 2015 (Swazan and Das, 2022). Therefore, lean practices in Bangladesh have been suffering already. In the middle of this pandemonium, the desire to implement lean has waned, creating additional barriers on top of those already in place (Islam, 2020).

2.2 Barriers affecting the lean implementation in COVID-19 pandemic

A list of barriers was proposed based on the literature review of Kabir *et al.* (2021), Parmar and Desai (2020), Basher *et al.* (2022), Mishra *et al.* (2021), Abu *et al.* (2019), Singh and Rathi (2021), Bashar and Hasin (2019), which consists of several barriers and challenges to lean implementation. Kabir *et al.* (2021) claims that LM may suffer from a lack of internal and external financing. Moreover, lack of intensive communication is also mentioned as a barrier by the authors. According to Singh and Rathi (2021), weak technological infrastructure has proven to be a major challenge to support any lean activities in the apparel sector. Parmar and Desai (2020), stated that lack of strategic reward and performance management prevent employees from participating in lean and continuous improvement activities. Bhadu *et al.* (2022) and Maware and Parsley (2022) found that organizations are often monolithic in nature and less willing to change management structure according to changing times. Mishra *et al.* (2021) identified insufficient time as a drawback to leanness, especially in the context of COVID-19. The authors also mentioned inadequate skills of worker and negative attitude toward lean hinders lean implementation. Bashar and Hasin (2019) maintained that employees often lack the core understanding of lean concept and how to implement lean tools. Thus, lack of proper understanding of lean concept is identified as a barrier. On the other hand, Abu *et al.* (2019) and Hasan *et al.* (2022) both mentioned improper selection and customization of lean tools as a significant cause preventing lean implementation. A total of 17 critical lean implementation barriers were chosen based on existing research and expert opinion that have been shown in Table 1.

2.3 Existing methods and rationale behind the proposed method

In previous research studies, a number of lean implementation methodologies were proposed. Researchers and academics have proposed a number of models to help management and professionals understand how to implement an effective improvement strategy. The vast majority of these models are founded on various theories of multi-criteria decision-making including the analytical hierarchal process (AHP), analytical network process (ANP) (Wong *et al.*, 2014), Interpretive Structural Modeling (ISM) (Jadhav *et al.*, 2014; Bhadu *et al.*, 2022), Decision Making Trial And Evaluation Laboratory (DEMATEL) approach (Singh and Rathi, 2021), etc. On the other hand, some literature have focused and performed their studies based on total interpretive structural modeling (TISM). Such as, Ramiya and Suresh (2021), Chaple *et al.* (2021) and Vinodh (2020) have performed some studies based on modeling the barriers of lean

No.	Barriers	References
1	Lack of internal and external funding	Kabir *et al.* (2021), Munim *et al.* (2022)
2	Weak technological infrastructure	Singh and Rathi (2021)
3	Lack of strategic reward and performance management	Parmar and Desai (2020), Basher *et al.* (2022)
4	Inadequate managerial skill	Expert suggestion
5	Low priority from the top management	Expert suggestion
6	Lack of efficient consultants and trainers	Expert suggestion
7	Lack of effective horizontal and vertical leadership	Expert suggestion
8	Resistance to change management	Bhadu *et al.* (2022), Maware and Parsley (2022)
9	Lack of awareness of the advantages	Mishra *et al.* (2021)
10	Lack of intensive communication	Kabir *et al.* (2021)
11	Lack of synchronization in strategic planning	Mishra *et al.* (2021)
12	Inadequate skills of worker	Mishra *et al.* (2021)
13	Negative attitude toward lean	Mishra *et al.* (2021)
14	Improper selection and customization of lean tools	Abu *et al.* (2019), Hasan *et al.* (2022)
15	Lack of proper understanding of lean concept	Bashar and Hasin (2019), Maware and Parsley (2022)
16	Lack of strategic reward and performance management system	Parmar and Desai (2020)
17	Lack of data preservation and progress tracking	Jadhav *et al.* (2014)

Source(s): Author's own contributions
Adopted from Kabir *et al.* (2021), Parmar and Desai (2020), Basher *et al.* (2022), Mishra *et al.* (2021), Abu *et al.* (2019), Singh and Rathi (2021), Bashar and Hasin (2019), Hasan *et al.* (2022), Munim *et al.* (2022), Bhadu *et al.* (2022), Maware and Parsley (2022)

Table 1.
Lean implementation challenges and barriers faced by Bangladeshi apparel industry

implementation utilizing the TISM method. In addition, Jain *et al.* (2023) have devised a TISM methodology to analyze the factors that would make it easier for Indian manufacturing facilities to undertake mass customization. In this research, a novel framework integrating Delphi method and fuzzy TISM has been proposed for examining and modeling the barriers of lean implementation. The purpose of the Delphi approach is to improve the reliability of subjective evaluations by gathering qualitative data and opinions from experts via a standardized questionnaire and a series of face-to-face sessions (Hasson and Keeney, 2011). The justification for employing the Delphi approach in the present study is that lean implementation is a complicated challenge requiring systematic analysis of expert opinions that are prone to subjectivity (Goodman, 1987). Although the Delphi approach yields a better expert opinion, one of its drawbacks is that it cannot be used to identify the causal relationships between the variables. The suggested decision support framework overcomes this shortcoming by combining the Delphi technique with fuzzy TISM. To our knowledge, no prior study has, however, suggested using the fuzzy TISM model based on the Delphi method to analyze the barriers to LM in the context of the COVID-19 pandemic. Such integration is a unique strategy that also strengthens the process by obtaining more precise feedback from the experts, increasing its robustness.

2.4 Research gaps and contributions

Numerous studies have explored how lean can be implemented in the past. For example, Salonitis and Tsinopoulos (2016) have made an effort to identify the barriers and drivers of lean implementation in the Greek manufacturing industry. Shah and Hussain (2016) and Mohan Prasad *et al.* (2020) also performed similar studies on the textile industry in Pakistan and India, respectively. Hasan *et al.* (2022) put their effort into finding out the current situation in lean implementation in the Bangladesh apparel industry. Despite the fact that a number of

studies have been done analyzing the impact of COVID-19 on Bangladesh's ready-made garment industry, they were mostly concerned about its impact on garments workers. Sen and Antara N (2020) and Kabir *et al.* (2021) tried to evaluate the impact of COVID-19 on Bangladeshi garments workers. But there were no studies conducted regarding the new challenges the novel coronavirus has brought in lean implementation. After an extensive literature review, it was found that there was very little light shed on the barriers to implementing lean in Bangladesh in the wake of a new virus, COVID-19. Lean implementation was already a challenge in the apparel industry of Bangladesh. But the novel coronavirus has brought new challenges to this already complex problem. In this study, the writers categorized and ranked the barriers of lean implementation in the Bangladesh apparel industry.

3. Research method

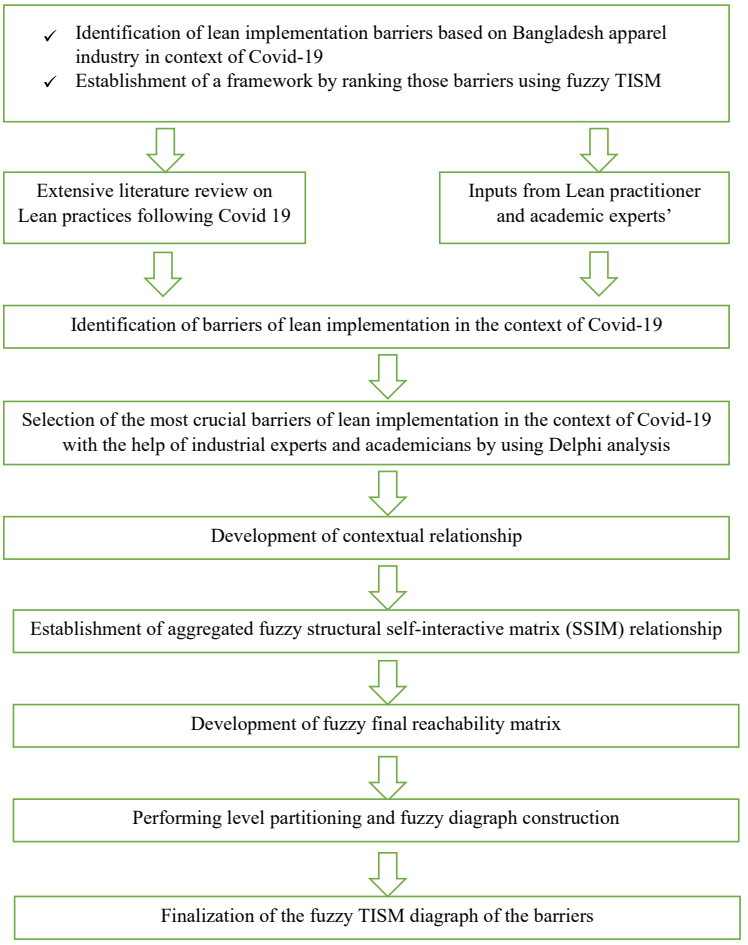
This research will aim to construct framework to identify and analyze the barriers of LM implementation in ready-made garment (RMG) industry of Bangladesh as an emerging economy in the context of COVID-19. Many RMG companies of Bangladesh are facing challenges to implement the LM concepts due to lack of proper understanding the influential relationships among the barriers. Therefore, this study has considered this context to develop a novel framework. The main phases of this study are shown in Figure 1.

3.1 The Delphi technique

The first phase of data collection consisted of Delphi method where the relevant barriers of lean implementation were finalized. The Delphi method needs between 12 and 15 respondents to ensure consensus (Linstone and Turoff, 1975; Vogel *et al.*, 2019). So, an expert panel including 12 professionals and five academicians was selected through purposive sampling method (Linstone and Turoff, 1975). The inclusion criteria for experts were years of experience, expertise in the relevant field and employment (Linstone and Turoff, 1975). The resulting panel of experts comprised academics and business people with more than 10 years of expertise in LM. The backgrounds of these eminent individuals are shown in Table 2 below. In this Delphi phase, three rounds of meeting were conducted. In the first round, the list of initially identified barriers of lean implementation from the literature was analyzed in relation to RMG industry of growing economy during the COVID-19 pandemic. In the second round, the experts were allowed to add new barriers and remove any irrelevant barriers from the list. In the final round, 11 barriers were selected for further analysis. The list of barriers that have been completed and are relevant to the setting of the rising economy is shown in Table 3.

3.2 Fuzzy TISM method

3.2.1 Total interpretive structural modeling (TISM). Structural models are concerned with the modeling process, which first emphasizes on identifying the model's fundamental components and then analyzes how these elements interact. Interpretive structural modeling's (ISM) primary goal is to establish connections between the parts under consideration, which helps people better understand how the system is structured (Jena *et al.*, 2017). So, ISM's interpretation of links is not very good because it does not explain how the directed links will create the relationship that was asked for. To aid decision-making, the generated digraph showing how the detected elements connect to each other should be appropriately comprehended (Sushil, 2012; Jena *et al.*, 2017). As a result, ISM is combined with the interpretive matrix, leading to the establishment of a comprehensive methodology and framework of total interpretive structural modeling (TISM) (Sushil, 2012). According to Sushil (2012) and Jena *et al.* (2017) TISM, a new expansion of classic ISM, is a qualitative



Source(s): Author's own contributions

Figure 1.
Flowchart of the current research

modeling approach that shows how each pair of elements in a matrix cell may be either binary or fuzzy, depending on the nature of the relationship between them.

3.2.2 Fuzzy total interpretive structural modeling (fuzzy TISM). By including an interpretative matrix into the structural model, TISM is designed to address the primary weakness of ISM, which is its inadequate interpretation of the relationships (Sushil, 2012). TISM is a modeling technique where a digraph model represents the contextual connections, full structure and interpretation for both substantial and direct transitive links (Jena *et al.*, 2017). In order to make the explanation of the structural model completely interpretative, previous research (Fan and Liu, 2010; Chen *et al.*, 1992; Jena *et al.*, 2017) have sought to upgrade ISM to TISM. Furthermore, the significance of applying fuzzy TISM has been emphasized, but the procedure model for implementing it in real world decision making is not delivered (Sushil, 2012). Moreover, theoretical contributions in the areas of adaptable management system and the integration of continuity and change management inspired the authors to develop the fuzzy TISM model (Sushil, 2012; Jena *et al.*, 2017). Thus, in their study

Experts	Size of industry	Experience level	Professional role
1	Large	21 years	Manufacturing Director
2	Large	17 years	Vice president, Lean Manufacturing Department
3	Medium	16 years	Assistant Director Supply Chain Department
4	Small	13 years	Head of Procurement
5	Small	12 years	Manager-Operations and Quality
6	Medium	11 years	Manager, Lean and Continuous Improvement Department
7	Medium	14	Industrial Engineer; Researcher
8	Large	10	Manager-Product Development
9	Medium	12	Manager-EHS
10	Large	16	Operation Specialist
11	Medium	14	Category Manager-SCM
12	Medium	11	Quality Production Leader
13	–	12	Associate Professor
14	–	15	Professor
15	–	15	Assistant Professor
16	–	18	Assistant Professor
17	–	12	Associate Professor

Source(s): Author's own contributions

Table 2.
Profiles of the experts in Delphi method

Code	Barriers	Source
B1	Lack of internal and external funding	Literature
B2	Lack of proper understanding of lean concept	Literature
B3	Lack of data preservation and progress tracking	Literature
B4	Lack of synchronization in strategic planning	Literature
B5	Improper selection and customization of lean tool	Literature
B6	Weak technological infrastructure	Literature
B7	Lack of strategic reward and performance management system	Literature
B8	Inadequate managerial skill	Literature
B9	Low priority from top management	Experts
B10	Lack of efficient consultants and trainers	Experts
B11	Lack of effective vertical and horizontal leadership	Experts

Source(s): Author's own contributions

Table 3.
The list of final barriers resulted from the Delphi method

authors have presented a framework for fuzzy TISM to investigate group preferences and understand the hierarchical link between components in a complex system while performing their tasks in a fuzzy environment (Khatwani *et al.*, 2015).

The proposed approach adapted from Khatwani *et al.* (2015), is a multi-criteria decision-making method that has been fuzzy extended. TISM is a useful method that is often used to find connections between various criteria by compiling a vast system of criteria that are both directly and indirectly related. The structural model may be completely understood by the fuzzy TISM model, which can assist managers in taking into account the links between considerable strength and discounting of weak strength (Khatwani *et al.*, 2015).

The computational steps of fuzzy TISM from Khatwani *et al.* (2015) are as follows:

Step 1: Start of decision-making process

Step 2: Selection of criteria

Step 3: Gathering responses and creating a structural self-interaction matrix (SSIM)

Step 4: Calculation of aggregated SSIM and final fuzzy reachability matrix

Step 5: Calculation of driving power and dependence for fuzzy MICMAC analysis

Step 6: Reachability matrix level partition

Step 7: Constructing fuzzy TISM digraph

In the second phase, data were collected for fuzzy TISM to analyze the influential relationship between the barriers. A questionnaire was prepared a format convenient to elicit information for fuzzy TISM analysis. An email with this questionnaire was sent out to the experts who had been previously chosen. After collecting the information, the fuzzy TISM was applied. Table S1 contains a list of linguistic expressions and their corresponding linguistic values which is adapted from Khatwani *et al.* (2015).

4. Analysis and results

4.1 Results of the study

This section represents the findings of the application of the proposed fuzzy-TISM framework to explain the relationships among the barriers of lean implementation in Bangladesh's RMG business in relation to COVID-19. In order to determine the link between the factors connected to the study work's purpose, an expert committee made up of academic and industrial specialists was formed (Step 1). From the previously published studies and expert recommendations as stated in Section 3.1, 11 barriers have been identified (Step 2). In the view of the professionals, the fuzzy structural self-integrated matrix (SSIM) of the barriers of lean implementation was developed for each expert (Step 3). Fuzzy linguistic scale from Table S1 was used to define the influential relationship between two barriers. The aggregated fuzzy SSIM as represented in Table S2 was constructed by taking the mean value of the responses from the experts. The interpretive matrix was developed from the aggregated fuzzy SSIM as shown in Table S3 (Step 4). The following stage included replacing the linguistic variables with the relevant triangular fuzzy number to create the final fuzzy reachability matrix from the aggregated fuzzy SSIM (Step 4). Table S4 represents the final fuzzy reachability matrix of the barriers of lean implementation. The final reachability matrix was used to compute each barrier's driving and dependency power (Step 5). Table 4 shows the value of driving power and dependence power of each barrier. According to the driving power, the top five barriers of lean implementation are B4, B2, B9, B1 and B7. Again, based on the dependence power values, the top five barriers are B5, B10, B11, B7 and B8. Based on these data, Fuzzy MICMAC analysis has also been conducted (Step 5). Figure 2 shows the result of the fuzzy MICMAC analysis. Fuzzy MICMAC has divided the barriers into two categories: linkage and

	Driving power			Dependence power		
Barrier	Fuzzy value	Crisp value	Rank	Fuzzy value	Crisp value	Rank
B1	[5.25,7.75,9.75]	0.6094	4	[4.25,6.75,8.5]	0.4812	7
B2	[6.75,9.25,11]	0.7675	2	[3.25,5.75,8.25]	0.3728	10
B3	[2.25,4.75,7.25]	0.3030	9	[4.5,7,9]	0.5201	5
B4	[7.5,10,11]	0.8438	1	[3.75,6.25,8.5]	0.4620	8
B5	[2.25,4.75,7.25]	0.3030	9	[5.25,7.75,10.25]	0.6272	1
B6	[3.5,6,8.5]	0.4343	7	[4.25,6.75,9]	0.4940	6
B7	[4.25,6.75,8.75]	0.5027	5	[4.75,7.25,9.25]	0.5525	4
B8	[3.75,6.25,8.75]	0.4869	6	[4.5,7,9.25]	0.5261	3
B9	[6,8.5,10.75]	0.6934	3	[4,6.5,8.5]	0.4555	9
B10	[3.25,5.75,8.25]	0.4081	8	[4.75,7.25,9.5]	0.5582	2
B11	[3.25,5.75,8.25]	0.4343	7	[4.75,7.25,9.5]	0.5582	2

Source(s): Author's own contributions

Table 4. Driving power and dependence power from fuzzy final reachability matrix

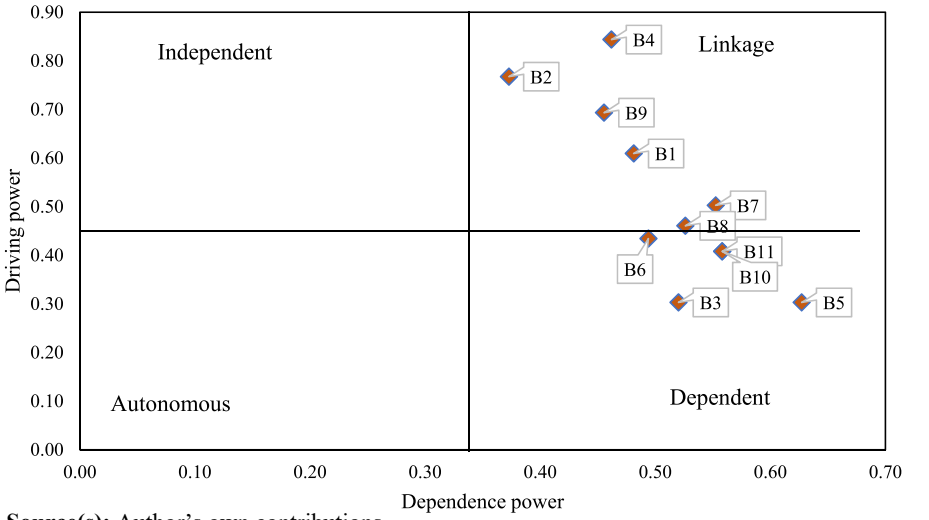


Figure 2.
Driving and dependence power matrix (Fuzzy MICMAC) of barriers of LM

Source(s): Author's own contributions

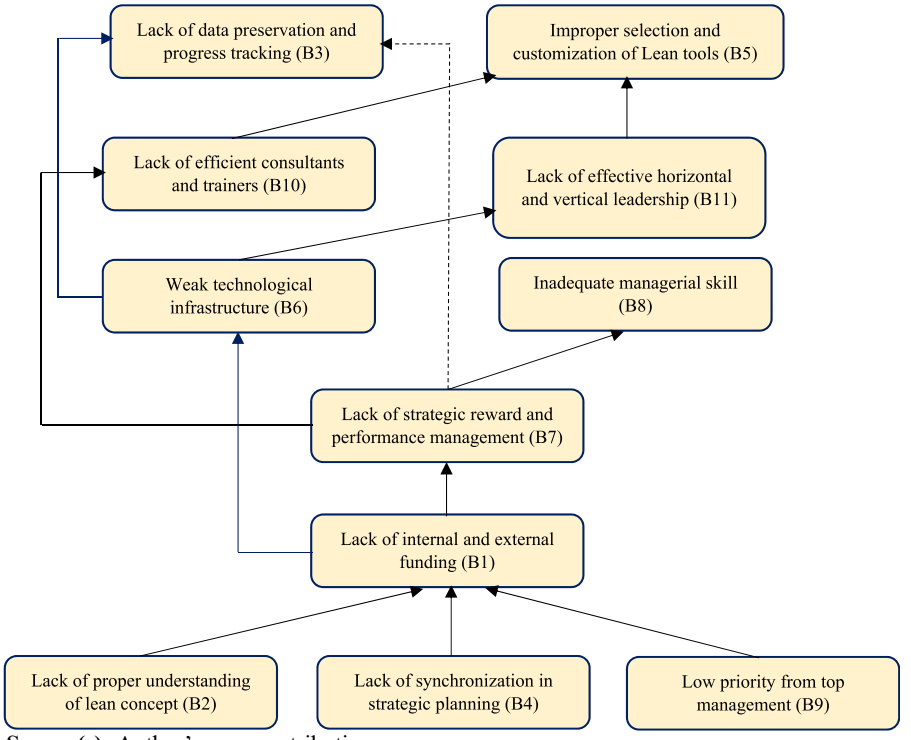
dependent. B1, B2, B4 and B9 have been grouped into linkage category. On the other hand, dependent category includes B3, B5, B6, B10 and B11.

Hierarchical relationship diagraph is one of the major outcomes of fuzzy TISM. To construct the diagraph, the defuzzified initial reachability matrix was created using the combined fuzzy SSIM according to Jain and Soni (2019). In Step 6, linguistic expressions "Very high" and "High" were expressed as "1" and "Very low", "Low" and "No" were expressed as "0". Table S5 represents the defuzzified initial reachability matrix. Then the final reachability matrix was built after checking and defuzzing the transitivity ties between the barriers as shown in Table S6 (Step 6). Level partitioning has been performed from the defuzzified final reachability matrix to explain the relationships among the barriers in a hierarchical form. Table S7 represents the level partitioning of barriers of lean implementation.

From Table S7 it can be seen that B3 and B5 are at Level 1. B10 and B11 are found at Level 2. Level 3 consists of B6 and B8. Level 4 and Level 5 include B7 and B1, respectively. Finally, B2, B4 and B9 are found at Level 6. Figure 3 shows the fuzzy TISM digraph which is the graphical representation of barriers of LM in level. The influential relationships among the barriers were represents through links and different levels in this fuzzy TISM diagraph (Step 7).

4.2 Validation of results

In this part of the study, the ranking of the barriers, fuzzy MICMAC matrix and fuzzy TISM diagraph were further validated with the help of industry practitioner. A series of focus group discussions were conducted in three phases, which involved 12 industrial managers to validate the research findings. The selection criteria for the participants included their years of working experience, current organizational affiliation and area of expertise. Specifically, participants were chosen based on having at least 15 years of working experience, currently working in a manufacturing organization and possessing knowledge of LM principles. In the first phase, the ranking of lean implementation barriers in the context of post COVID-19 was given to the participants for validation. After the discussion, the participants reached a consensus on the ranking of barriers. During the second phase, the participants were asked to validate the barriers within each class of fuzzy MICMAC matrix. This was done to ensure that the barriers identified in the first phase were accurately categorized and accounted for within



Source(s): Author's own contributions

Figure 3.
Fuzzy TISM diagraph of barriers of lean implementation

the classes. Finally, the fuzzy TISM diagram was presented to the participants along with a hierarchical relationship among the different barriers. The participants were asked for their opinions on the direct and indirect relationships among the barriers, and whether they were appropriate in the context of post COVID-19. The participants expressed that they found the direct and indirect relationships among the barriers to be appropriate and relevant in the current context. Overall, this phase helped to further validate and refine the identified barriers, and provided a deeper understanding of the relationships among them.

5. Discussion and implications of the study

5.1 Discussion of the findings

The findings from the application of the proposed methodology provide some insights about lean implementation challenges in apparel business of Bangladesh in the context of COVID-19. The findings reveal that "lack of synchronization of lean planning with the strategic planning", "lack of understanding of lean concept" and "lack of priority from the top management" are the three top most important barriers of LM implementation in apparel industry of Bangladesh during the pandemic of COVID-19. A decision-support framework to analyze and model the influential relationships among the barriers has been presented in Figures 2 and 3. These findings will help the apparel sector to formulate strategy for implementing the LM practices successfully.

In accordance with the data shown in Table 4, B4 is the most significant barrier according to the driving power value to implement LM in RMG industry. Most of the RMG companies

have to change their strategic planning to mitigate the disruptions resulted from the recent COVID-19 pandemic. However, most of the RMG companies of emerging economy like Bangladesh are failing to synchronize the LM strategy with their company strategy. Improper alignment of LM strategy with the company strategy cannot bring the intended benefits for the companies (da Silva *et al.*, 2021). The second most significant barrier has been identified as B2. The traditional LM must be rethought by the RMG companies as the industry context has been changed significantly after the pandemic. Companies of emerging economy are trying to initiate LM tools to tackle these business transformations in the traditional way. However, lack of knowledge about the LM concept makes them unable to adopt new ways to implement the lean successfully in the context of COVID-19 (Liao and Wang, 2021). Moreover, due to lack of sufficient understanding and knowledge, companies' top management usually fails to give enough priority to adopt LM concept. This study has also found the B9 as the third most significant barrier to implement LM concept. Successful implementation of LM requires high investment priority and close attention from the top management (Vanichchinchai, 2021). However, after the COVID-19 outbreak, the focus of most RMG firms in developing economies has switched away from operational strategy and toward finance and market strategy. From Figure 2, it can be seen that all these three barriers are in the linkage cluster as they have close relationship with the other barriers. Moreover, Figure 3 implies that these barriers have influential relationship among themselves as well as with other barriers.

During the COVID-19 pandemic, the successful implementation of LM concept requires substantial amount of internal and external funding as most companies are facing financial crisis in emerging economy. However, lack of proper strategy and knowledge as well as low priority from the companies can lead to B1. Figure 3 shows that B2, B4 and B9 directly influence B1. Moreover, this barrier has been found as the fourth significant barriers according to the driving power value. Leite *et al.* (2022) has also found that lack of sufficient financial support is one of the major causes of lean implementation failure. Again, successful implementation of LM concept requires active participation of employees and workers of all the levels of the company. Therefore, proper motivation is needed through incentives and rewards to engage them for implementing the LM. However, B7 will fail to keep them motivated and eventually, the implementation of LM will be in vain. Vinodh (2020) also identified that lack of proper reward system is one of the major barriers to implement LM successfully. Figure 2 shows that B7 is also grouped into linkage cluster as this barrier has significant relationships with other barriers. From Figure 3 it can also be seen that B7 directly influences the B8. Skilled employees of managerial levels play significant roles in successful lean implementation as they coordinate the overall implementation process and work as a bridge between the top management and lower level employees in the company (Singh and Rathi, 2021).

Recently, many RMG companies in the emerging economy are trying to adopt modern technologies to improve their operational performances during the COVID-19 pandemic. However, most of them have failed due to lack of sufficient funding and resources. This study also revealed that B1 influences the B6 as shown in Figure 3. According to Abu *et al.* (2021), weak technological capabilities of the company can adversely affect the successful implementation of LM. During the lean implementation process, it is required to continuously track the progress and analyze the data. Figure 3 depicts that B3 is resulted from the B6. Figure 3 also shows that B6 and B8 lead to B11. Moreover, B10 is resulted from B7. Effective leadership reconciles the successful lean implementation strategies with the company strategy (Singh and Rathi, 2021). Again, there is lack of experts and effective trainers in emerging economy for implementing the LM successfully (Gaikwad *et al.*, 2020). However, these two barriers are often resulted from the previously discussed barriers. This study has also found these two barriers as the second most dependent barriers as shown in

Table 4. Finally, lean concepts and tools need to be customized according to the context of emerging economy. However, B10 and B11 can lead to B5 as shown in Figure 3. This has been found as the most dependent barriers while implementing LM concept in RMG industry of Bangladesh. According to the fuzzy MICMAC as shown in Figure 2, B3, B5, B6, B10 and B11 fall into dependent category. While analyzing the fuzzy TISM diagraph, it has been found that all these five barriers are somewhat influenced by the other barriers.

5.2 Theoretical and managerial implications

To the authors' knowledge, no prior work has combined Delphi technique, Fuzzy set theories, TISM model and LM to suggest an evaluation strategy. As a result, this study contributes to the theory of many disciplines since it unites a wide range of issues into one. From the perspective of the COVID-19 epidemic, it offers a comprehensive picture of lean implementation barriers and challenges faced by Bangladesh RMG industry. Based on apparel sector of Bangladesh, there has only been a little amount of study conducted on these problems (Hasan *et al.*, 2022; Bashar *et al.*, 2021; Kabir *et al.*, 2021; Munim *et al.*, 2022). There was no assessment of the barriers imposed by COVID-19 by the writers of those papers. In order to better understand the relationship between the application of lean approaches and the barriers that stand in the way of doing so, the authors of this study set out to look into the COVID-19 pandemic and its effects on the organizations. Authors have developed a structural model that interprets the transitive and causal connections of the lean implementation barriers in RMG industry of Bangladesh, and also outlines how those elements interrelate with one another by utilizing Fuzzy-TISM. In terms of theoretical contribution, it highlights a new set of lean implementation barriers and numerous cause-effect correlations to assist minimize the pandemic impact of LM implementation. As a final point, the article included a full explanation of the construction process and suggestions for its implementation. Academics and researchers may use this study to learn more about how this method could be used in different contexts.

The current study highlights possible methods that managers in the RMG sector of Bangladesh may take to assist to reduce the COVID-19 pandemic's effects on the RMG sector by adopting LM. Many professionals working in this field will benefit from the results of this research since it shows them how their manufacturing processes may be affected by the COVID-19 pandemic and how they may reduce such effects. Additionally, Most of the RMG companies have to change their strategic planning to mitigate the disruptions resulted from the recent COVID-19 pandemic (Hasan *et al.*, 2022). However, most of the RMG companies of emerging economy like Bangladesh are failing to synchronize the LM strategy with their company strategy (Hasan *et al.*, 2022). Improper alignment of LM strategy with the company strategy cannot bring the intended benefits for the companies (da Silva *et al.*, 2021). Therefore, policy makers should prioritize the implementation of lean in their industries for the overall benefit. As a result, it is suggested that managers prioritize the barriers and challenges and develop suitable methods to overcome them in order to adopt LM successfully. So, the findings of the study may aid companies in making decisions about developing distinctive lean implementations and transforming current systems into competitive ones.

5.3 Implications for sustainable development goals

The model, constructed on the suggested fuzzy TISM framework, will aid in the formulation of successful strategies for the introduction of LM and, by extension, the attainment of sustainability goals (SDGs). The second most significant barrier has been identified as "Weak technological infrastructure (B2), one of the influential barriers of LM. During the COVID-19 pandemic, the successful implementation of LM concept requires substantial amount of internal and external funding as most companies are facing financial crisis ("Lack of internal and external funding -B1") in emerging economy. As a result, businesses may receive

assistance in building LM infrastructures and encouraging innovation during the COVID-19 pandemic, all of which will lead to the growth of long-term, sustainable Industry, Innovation, and Infrastructure (SDG 9). Companies can promote awareness of advantages of LM in their organization by incorporating proper consultants and trainers which ("Lack of awareness of the advantages-B8" and "Lack of efficient consultants and trainers-B6") will aid in developing resilient LM and lowering product waste, two key components of Responsible Consumption and Production (SDG 12). Lean philosophy encourages maintaining a model of organization focused on elimination of waste to reduce the overall costs, ensuring timely delivery of quality products and materials while respecting people and the environment. So, finding and removing the appropriate barriers of LM implementation can help achieve sustainability in the RMG industry which can facilitate a sustainable transition toward the successful implementation of lean.

As, achieving increasing levels of economic productivity via diversification, technical upgrading and innovation, notably by concentrating on high-value added and labor-intensive industries, is an aim of sustainable development goal (SDG 8) so it can be obtained by proper lean implementation in an organization. Thus, the proposed model is expected to contribute to Responsible Consumption and Production (SDG 12); Decent Work and Economic Growth (SDG 8); Industry, Innovation and Infrastructure (SDG 9) via resilient strategies.

6. Conclusion and future scopes of the study

Apparel businesses have the opportunity to reap certain benefits by using LM systems, which may lead to increased productivity, improved quality, reduced inventory, shorter lead times, more customer satisfaction, better sales and greater profitability. A large amount of research demonstrates that adopting lean production methods may potentially resolve many of the issues linked to Bangladeshi RMG manufacturing. Previous studies on the Bangladeshi RMG industry had not yet identified the barriers or discovered the relationships between those barriers throughout the difficult period that is now going on due to COVID-19 situation. In light of these findings, the study examined the barriers to lean adoption in the apparel sector of Bangladesh. The current investigation constitutes a new approach to describe and determine the links in the barriers that appear in a hierarchical manner. A Delphi based Fuzzy TISM method was used to investigate and evaluate how the barriers are related to one another. To comprehend and analyze interactions between barriers, the digraphs model was developed. The use of fuzzy in TISM enables policymakers to assess the degree of correlation between barriers. The fuzzy TISM diagraph depicted the important connections among the barriers via links and levels, which will assist policy-makers eliminate the influential barriers sequentially and adopt lean in their industry. The management of RMG organization should consider the given framework of the barriers in order to design effective strategies and policies for lean implementation.

Additionally, it is necessary to highlight the research's shortcomings in this article. The present study is based on an extensive review of the literature and diverse expert opinions, which may be ambiguous. The goal of this research was to ascertain the general pertinency of RMG organizations in Bangladesh. So, the results may differ for different countries, businesses of various sizes, different industries, and more. Potential researchers may apply ISM, AHP, Fuzzy DEMATEL, Grey DEMATEL and similar methods. In addition, scholars should evaluate the whole of the manufacturing sector in this circumstance.

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Appendix

The supplementary material for this article can be found online.

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