The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/2977-0114.htm

Received 4 October 2023
Revised 24 February 2024
Accepted 2 April 2024

The pathways to lean manufacturing for circular economy: Implications for sustainable development goals

Sheak Salman and Hasin Md. Muhtasim Taqi
Department of Mechanical and Production Engineering, Ahsanullah University of Science and Technology, Dhaka, Bangladesh

S.M. Shafaat Akhter Nur
Department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh

Usama Awan
Department of Economics, Inland Norway University, Lillehammer, Norway, and

Syed Mithun Ali
Department of Industrial and Production Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh

Abstract

Purpose – This study aims to address the critical challenge of implementing lean manufacturing (LM) in emerging economies, where sustainability complexities on the production floor hinder production efficiency and the transition towards a circular economy (CE). Addressing a gap in existing research, the paper introduces a path analysis model to systematically identify, prioritize and overcome LM implementation barriers, aiming to enhance performance through strategic removal.

Design/methodology/approach – The authors used a mixed-method approach, combining empirical survey data with literature reviews to pinpoint key LM barriers. Using the grey-based Decision-Making Trial and Evaluation Laboratory (DEMATEL) along with the Network Knowledge (NK) method, they mapped causal relationships and barrier intensities. This formed the basis for developing a path simulation algorithm, integrating heuristic considerations for practical decision-making.

Findings – This analysis reveals that the primary barriers to LM adoption is the negative perception and inadequate understanding of lean tools and CE principles. The study provides a strategic framework for managers, offering new insights into barrier prioritization and overcoming strategies to facilitate successful LM adoption.

Research limitations/implications – This research provides a strategic pathway for overcoming LM implementation barriers, empowering managers in emerging economies to enhance sustainability and

Journal of Responsible Production and Consumption
Vol. 1 No. 1, 2024
pp. 18-38
Emerald Publishing Limited
2977-0114
DOI 10.1108/JRPC-10-2023-0009

competitive advantage through LM and CE integration. It emphasizes the significance of structured barrier management in the manufacturing sector.

Originality/value – This research pioneers a systematic exploration of LM implementation barriers in the CE context, making a significant contribution to the literature. It identifies, evaluates barriers and proposes a practical model for overcoming them, enriching sustainable manufacturing practices in emerging markets.

Keywords Barrier interactions, Circular economy, DEMATEL-NK, Lean manufacturing, Path analysis

Paper type Research paper

1. Introduction

Lean management is an emerging approach to identifying and eliminating waste throughout a manufacturing supply chain (Hasan *et al.*, 2022). This ideology encourages companies to adopt production standards to improve operations and cut costs by eliminating unnecessary manufacturing steps that add no value to the product. Industrial and service organizations use lean manufacturing (LM) because they must manufacture and satisfy consumer needs (Silvestri *et al.*, 2022). LM and process improvement make long-term supply chain and organizational success simpler (Awan *et al.*, 2022; Shen, 2020). As a result, industrial companies of all types have become conscious of the need to improve their performance in the face of competition and have adopted LM to accomplish continuous development. According to the research of Kumar *et al.* (2022), Bashar *et al.* (2021), Yadav *et al.* (2020) and Alkhoraif *et al.* (2019) LM has benefitted a wide spread of industry variations mainly modifying the operational parameters such inventory cost, handling cost, quality control cost, by keeping them as low as possible. This manufacturing practice is viewed as a fast-growing norm in developing countries with emerging economy for its well-paid returns (Mathiyazhagan *et al.*, 2022). On the other hand, in the age of Industry 4.0, there's a rise in the creation of new technologies aimed at enhancing connectivity and automating procedures through the integration of lean six sigma (LSS) principles (Tissir *et al.*, 2023). Tissir *et al.* (2023) proposed a framework merging the Industry 4.0 and LSS to extract the impact of overall performance of the firms.

However, the extent of LM practices contributing to circular economy (CE) is not clear (Kurdve and Bellgran, 2021). According to Ciliberto *et al.* (2021), there has been a long-standing understanding gap between implementing LM and "performance of CE at micro level in manufacturing". Although the manufacturing firms in emerging countries has been expanding rapidly in the last few years, but there is lack of understanding in implementing lean for CE (Kurdve and Bellgran, 2021). A paradigm change toward an innovative and more sustainable supply chain ecology is necessary for the transition to CE (Zhang *et al.*, 2019). To accelerate the transition to achieve sustainable circularity of the material, firms face difficulties in understanding in planning and implementing sustainable production initiatives due to lack of different operational, structural and management barriers. Existing literature on LM and CE reveals that there is no single and universal management approach that drive production competitiveness (adding value by increasing economic efficiency) and circularity of material (exploit and maximize the resources) (Ciliberto *et al.*, 2021). This creates a challenge for manufacturing firms on when and how different internal and external organizational-related barriers create hurdles in implementing LM for improvement of re-used, re-manufactured and recycled products (Kurdve and Bellgran, 2021). In addition, Cherrafi *et al.* (2016) conducted a review study examining the literature pertaining to the integration of lean, six sigma and sustainability, as well as the emerging issues within this domain. Authors suggested that there are seven major drawbacks to develop an integration model of lean, six sigma and sustainability. The authors investigated the combined influence of total productive maintenance, Industry 4.0 (I4.0) and CE on the sustainability performance (SP) of manufacturing companies in their study (Samadhiya *et al.*, 2023). The authors Luthra *et al.* (2021) mentioned in their study that CE has a beneficial impact on manufacturing firms' SP. Thus, it is inevitable for the firms to make progress towards LM that is likely to improve CE (Ciliberto *et al.*, 2021). Thus, understanding solutions and tools is necessary for firms to reduce and avoid environmental problems (Kurdve and Bellgran, 2021).

As a result, industrial companies of all types have become conscious of the need to improve their performance in the face of sustainability competition and have adopted LM to accomplish continuous development. However, previous research suggests that Bangladesh, a promising country of emerging economy being labelled as "Asian Tiger" by "The Economist" for its indomitable run of success in economic prospect (Ulfy, 2020). Light engineering, construction material manufacturing and textile manufacturing sectors of Bangladesh are seeing extensive growth since the past decade and also contributing to the national gross domestic product (Khan *et al.*, 2020). However, the high cost of manufacturing, the inefficient use of resources and the resulting high wastes are on the rise and cannot be resolved quickly. Bangladesh's light manufacturing industry is one of the most prominent examples of the aforementioned difficulties, such as health risks and inadequate technology use. Continuous improvement is the key to addressing these difficulties to eliminate waste and optimize efficiency; this is the essence of LM practice (Maware *et al.*, 2022). Today lean philosophy has extensive impact on worldwide production system and even more in countries with emerging economy (Naeemah and Wong, 2022; Agyabeng-Mensah *et al.*, 2021) and it is closely linked with the CE (Ciliberto *et al.*, 2021). CE approaches focuses on the resource efficiency management (Ul-Durar *et al.*, 2023). Improvement in the CE outcomes requires firms to understand about the intensity of the organizational-level barriers (Ul-Durar *et al.*, 2023). Yadav *et al.* (2020) model showed that fewer manufacturing firms are successful in implementing LM to support waste management and material efficiency.

However, the link between the LM and CE outcomes has not been examined (Ciliberto *et al.*, 2021). Recent research by Badhotiya *et al.* (2022) and Abu *et al.* (2019) underlines the importance of barriers and drivers for the implementation of LM in different sectors. Yadav *et al.* (2020) found that manufacturing strategy, shopfloor process and supplier–customer management are creating more barriers than quality control practices in achieving desired outcomes of LM. Yet there are gaps on finding out the complex co-relation of multifaceted barriers and the optimal pathway to overcome these barriers for achieving CE outcomes (Ciliberto *et al.*, 2021). Despite the importance of LM and CE (Ciliberto *et al.*, 2021; Kurdve and Bellgran, 2021), their understanding of organizational-level barriers that hinder LM progress towards CE is still rudimentary (Ciliberto *et al.*, 2021). Generally speaking, previous literature provides two research limitations:

(1) most of the literature has examined LM perspective, while focusing on identification of the barriers or drivers (Yadav *et al.*, 2020); and

(2) past unexamined question is how LM influences on CE outcomes (Ciliberto *et al.*, 2021).

Little is known about the dynamics of different internal and external organizational related barriers that can affect the transition towards CE (Ul-Durar *et al.*, 2023). Although the literature shows convergence on LM and CE literature, while generating considerable discussion for firms transitions towards CE outcomes, there are little studies examining the barriers impact on firm transition towards CE outcomes using multicriteria decision making methods.

The purpose of the study is to add clarity into the ongoing discussion regarding LM and CE and to identify and assess the LM key barriers in manufacturing firms in developing economies to make successfully transition towards CE. This article addresses these gaps by combining academic research with an empirical survey to uncover lean implementation obstacles for CE. To put it more precisely, the study's research questions (RQs) are listed as follows:

RQ1. What are the barriers to the implementation of lean manufacturing in emerging economies firms and to analyse the inter-relationship among the barriers for CE?

RQ2. What is the optimal path for overcoming these barriers and enhancing lean implementation in manufacturing sector?

RQ3. How lean manufacturing adoption can enhance CE performances in manufacturing industry?

The study context of Bangladesh is suitable for this study for a number of reasons. Firstly, the high cost of manufacturing, the inefficient use of resources and the resulting high wastes are on the rise and cannot be resolved quickly is a major issue in the emerging economies. Secondly, the Bangladesh's light manufacturing industry is one of the most prominent examples of the aforementioned difficulties, such as health risks and inadequate technology use. The production system may be hindered if the manufacturing system is totally redesigned. To achieve these goals, a hybrid optimum barrier mitigation pathway analysis technique is developed that combines grey system theory, Decision-Making Trial and Evaluation Laboratory (DEMATEL) and Network Knowledge (NK) models to discover the most effective path forms for overcoming barriers and enhancing LM. To deal with the uncertainty of decision-maker's perspectives on mapping, grey numbers are used (Khadanga *et al.*, 2022). Grey groups DEMATEL is used to study the interactions between barriers and the intensity of their effects (Haseli *et al.*, 2023). The NK model is used to construct a predictive path search approach based on the identified causalities and intensities. In the NK model, the best path direction for overcoming barriers to lean implementation is found by visualizing and modelling the system's ascent to the pinnacle of the fitness landscape.

The relevant literature is described in the next part, and the methodology and model development are detailed in Section 3. The results are presented in Section 4 along with a discussion of the results. Section 5 explores the ramifications of the study, and Section 6 provides a thorough explanation of the study's findings and future scope.

2. Literature review

This section examines the literature on lean implementation barriers and challenges for enhancing CE in industrial firms. The outcomes of this examination are shown in Table 1. And then a short discussion on existing methods is presented. Finally, some research gaps and contributions in aspects of lean implementation are highlighted.

2.1 Lean manufacturing and circular economy

An age of continual change has entered the global economy. Customers' rising expectations, fierce rivalry and the necessity for firms to innovate and create ideas have prompted some industrial organizations to explore for strategies to maximize profit and equality without

Barrier codes	Name of the barriers	Evidence	References
B1	Weak link between lean and circular economy improvement programme	The company's overall plan does not include any lean improvement program implementation along with circular economy performance outcomes	(Deshmukh *et al.*, 2022; Shammi *et al.*, 2022; business *et al.*, 2013)
B2	Lack of training on sustainability and circular lean integration	There is a scarcity of qualified lean consultants and trainers, which exacerbates the problem A suitable sustainable lean training program is one of the best ways to increase individual understanding of waste categories, lean concepts and their links to sustainable performance	(Gil-lamata and Latorre-Martínez, 2022) Expert suggestion
B3	Inadequate information infrastructure (use of AI, IoT and Big Data analytics)	Adequate information infrastructure can help to increase the efficiency of production networks	(Polyakov *et al.*, 2021) expert suggestion
B4	Lack of digital platforms (challenges in merging lean with technological developments)	Digital platforms offer the potential to enhance interaction between producers and consumers. However, there are challenges involved in integrating lean principles with technological advancements	(Puram *et al.*, 2022; Polyakov *et al.*, 2021)
B5	Lack of senior management's interest and resistance to change	To successfully implement lean manufacturing, a company's mentality must shift significantly. This may be very difficult if the organization is not well-prepared for the changes. Limited interest towards lean strategies and wellbeing initiatives of lean implementation	(Abu *et al.*, 2022; Khan et al., 2020; Rahim, 2017)
B6	Lack of understanding of implementation cost and benefits of lean	Scarcity of knowledge on benefits of lean implementation	Expert suggestion
B7	Negative perception and lack of knowledge about lean tools along with circular economy	Managers and staff have a limited awareness of circular economy, lean concepts, principles and procedures. Inexactness of meaning of lean tools	(Abu *et al.*, 2019; hasan *et al.*, 2018; panwar *et al.*, 2015)
B8	Lack of management of resources and sustainable utilization of resources	Effective and efficient resource management and utilization is essential to achieving maximum sustainable lean management performance	Kabir *et al.* (2021) and expert suggestion
B9	Negative attitudes towards sustainable development	Companies have limited interest towards sustainable development programmes	(Gil-lamata and Latorre-Martínez, 2022; Salman *et al.*, 2024)
B10	Lack of green supply chain management approaches	Organizations should prioritize circular economy (CE) practices aimed at enhancing customer value while simultaneously conserving the environment	(Gil-lamata and Latorre-Martínez, 2022; Kabir *et al.*, 2021)

Source: Author's own contribution

Table 1.
The main barriers of lean manufacturing implementation to enhance circular economy

increasing prices. Most businesses have used the finest strategies for lowering production expenses, overcoming manufacturing challenges and reducing waste and losses in the manufacturing process to enhance the degree of efficiency to achieve the desired productivity and profit (Hama Kareem *et al.*, 2017). LM is one strategy for achieving this goal (Maware *et al.*, 2022; Bayat and Dadashzadeh, 2017). The aim of LM is to maintain minimum waste, fast response and low inventory while meeting consumer demand efficiently (Hama Kareem *et al.*, 2017). The advent of Industry 4.0 technologies brings forth fresh potential to improve the effectiveness and efficiency of CE adoption, particularly in the realm of waste management (Zhang *et al.*, 2021). In general, lean means manufacturing without waste (Yadav *et al.*, 2020). The majority of researchers have emphasized lean as a method for reducing waste. Palange and Dhatrak (2021) on the other hand, outlined lean as a strategy for providing maximum value to consumers by decreasing waste through human design and process aspects. According to Mostafa *et al.* (2013), lean is an efficient approach for improving operations efficiency through quality improvements, inventory reduction, distribution, productivity and cost reduction. Abu *et al.* (2019) and Karim and Arif-Uz-Zaman, (2013) published an extensive research on the environmental benefits that may be gained by using lean practices in business.

2.2 Lean implementation challenges and barriers to enhance circular economy performance

In the literature, several challenges and barriers to the incorporation of LM have been addressed. Panwar *et al.* (2015) highlighted that implementing LM requires a significant shift in a company's thinking, which may be challenging if the business is not well-equipped to manage the changes. He also stated that the main issue with managers and staff not knowing lean expertise, values and strategies is owing to a lack of knowledge about these ideas. Čiarnienė and Vienažindienė (2013) and Kabir *et al.* (2021) carried out a study on how poor communication between employees and industrial cultural issues affect to implement lean in the industry. Takeda-Berger *et al.* (2021) mentioned that there is a lack of information available about the advantages of implementing lean which impedes the practice of a proper lean tools. Hamja *et al.* (2022) focused on the perceptions of the company's executives that lean is complex to implement. Rahim (2017) stated that there is a scarcity of lean experts and trainers, a lack of understanding of lean as well which impedes implementation. However, Abu *et al.* (2019) have mentioned that the definition of lean tools is ambiguous to the employees. Management's lack of interest and support, training, time, technical knowledge, financial and human resources were identified as challenges to implementing lean in the industry by Abu *et al.* (2019). The authors delved into the challenges and barriers of implementing LM through an extensive literature review. To pinpoint these challenges, they conducted a systematic literature review (SLR). Table S1 (refer to the supplementary file) outlines the inclusion and exclusion criteria used in the SLR approach, drawing from the studies of Okoli and Schabram, (2010) and Jesson *et al.* (2011).

For this literature search, Google Scholar, Web of Science and the Scopus database were used between the years 2012 and 2022. As the databases are more reliable and provide powerful search tools for narrowing results, users are able to gather information more quickly and accurately that they need. A total of 1,800 research papers with the keywords mentioned above were found initially. After screening the 1,800 articles by using BOOLEAN Operators authors have finalized 120 articles for final review. Moreover, systematic literature search (Okoli and Schabram, 2010; Jesson *et al.*, 2011) has been done to aid in the identification of the barriers. Finally, in the last step, ten critical challenges of lean adoption were picked from those articles and expert opinion. To illustrate how those obstacles that impede implementation of LM are mentioned in Table 1.

2.3 Existing methods, research gaps and contributions of this study

Several lean implementation strategies have been offered in prior research investigations. Researchers and academics have proposed a range of models to assist management and professionals in understanding how to adopt effective improvement methods. Many of these models draw upon multi-criteria decision-making theories such as analytical hierarchical process, analytical network process (ANP), failure mode and effect analysis (FMEA), total interpretive structural modelling (TISM), fuzzy logic, DEMATEL approach, analysis of variance and genetic algorithm. Table S2 (see supplementary file) depicts some of the models developed by researchers to aid in the adoption of lean.

Existing studies have found a variety of lean development strategies. An implementation framework diagram has been made available in a number of scholarly papers (Schulze and Dallasega, 2023; Kaswan *et al.*, 2023; Mathiyazhagan *et al.*, 2022; Bhadu *et al.*, 2022; Mostafa *et al.*, 2013). Using a framework, Kumar *et al.* (2022) and Chauhan and Singh (2012) evaluated the condition of LM in the manufacturing sector. Chaple *et al.* (2018a) have used the TISM technique to present a model of the lean implementation challenges. Yadav *et al.* (2020) created a framework using a fuzzy DEMATEL methodology to help manufacturing organizations embrace LM practices. For the lean transformation, some studies have used roadmaps. Tortorella *et al.* (2021) have outlined several paths and roadmap that may lead to a successful application of LM. The implementation of lean and green practices was incorporated into the evaluation of organizational performance and a system improvement priority list was produced using the ANP methodology by Martínez *et al.* (2023) and Farias *et al.* (2019). In several academic studies, a conceptual framework was used to illustrate the implementation process (Mathiyazhagan *et al.*, 2022). Chaple *et al.* (2018a) have proposed the application of the interpretive structural modelling and interpretive ranking process methodologies to the study of various lean implementation strategies in the manufacturing sector. Thus, no study yet has focused to develop a path analysis model which is a combination of LM and CE. So, in this study, authors have focused on identifying the major drawbacks of LM implementation that hinder the performance outcomes of CE and developed a path analysis model that is novel in this field.

3. Model development

3.1 Samples and data collection

In the first place, the barriers pertaining to the implementation of lean practice are identified and confirmed by an extensive and intriguing literature review (Table 1). The barrier list was sent to the expert team consisting of 15 members, who have vast experience in different industries and are acting as the pioneer bodies for paving the path for lean implementation, as shown in Table S3 (see supplementary file). Purposive sampling was used to find experts who fulfil the study goals based on their field of work, expertise and years of experience (Table S3). Purposive sampling allows you to select respondents based on specific traits that can help with the problem at hand, while also assuring the optimum use of available resources and the validity of the results (Ali *et al.*, 2022). The list was sent through email and a google form was attached too for receiving the direct relationships between any of the two barriers and their respective influences from each expert. The barriers from Table 1 were evaluated and finalized against other barriers on the same list based on the grey scale depicted in Table S4 (see supplementary file). After that, we began with the five grey linguistic variable score matrices generated by the five experts' teams and use them as the input data.

3.2 The grey group DEMATEL-NK model

The traditional NK model is unable to immediately show the best way to mitigate the barriers that stand in the way of lean implementation, as the NK model's fitness values are meant to be dispersed randomly within the scope of the range (0,1) using a large number of stochastic experiments, taking into account the ambiguity and the degree of difficulty of the research topic. Furthermore, the fitness values derived are unable to convey the causal linkages and intensities between barriers. As a result, this work makes use of DEMATEL's attributes in exposing interactions between variables to correct the NK model (Sun *et al.*, 2022).

Then, due to subjective judgements, insufficient knowledge and the uncertainty inherent in the decision environment, it becomes impossible to quantify with precise numerical values. Thus, grey system theory's three-parameter interval grey numbers are utilized to circumvent inadequate knowledge and the ambiguities inherent in human judgement (Sun *et al.*, 2022; *Han et al.*, 2018). In addition, the present DEMATEL approach aggregates group information based on the mean, neglecting the linearity assumption (Sun *et al.*, 2022). So, to deal with grey information and unclear aggregation methods, the DEMATEL approach has been extended to include a new group aggregation strategy based on the simultaneous objectives of information difference and similarity. As a result, the DEMATEL-NK path simulation approach for the grey group is used in this study. It has the characteristics listed below:

- to map the ambiguous perceptions of decision-makers, grey numbers with a three-parameter interval are used, and multi-objective optimization is used to integrate the grey data from numerous expert groups; and
- using grey DEMATEL, the NK model's fitness landscape is generated, which extracts the complicated interaction mechanisms for the numerous challenges.

The NK search method is used to explore the fitness landscape, and from that the path simulation algorithm generates a path frame along with the outcome of the optimum search strategy. The steps of the grey group DEMATEL-NK model presented by Sun *et al.* (2021) is shown below:

Step 1: Set the system parameters
Step 2: Generate the initial grey group direct relation matrices
Step 3: Calculate the normalized grey direct relation matrix
Step 4: Calculate the grey total relation matrix
Step 5: Calculate the overall prominence and net effect
Step 6: Whiten the overall prominence and net effect
Step 7: Calculate the overall fitness values of every system configuration
Step 8: Determine the optimal path

The algorithm used in the process of simulating the ideal path is performed according to Sun *et al.* (2021) to determine the optimal path based on the 2^N feasible configuration's overall fitness values.

4. Results and discussion

4.1 The result analysis for finding the optimal path

The process for finding the optimal path considering the barriers which are listed in Table 1 are given below:

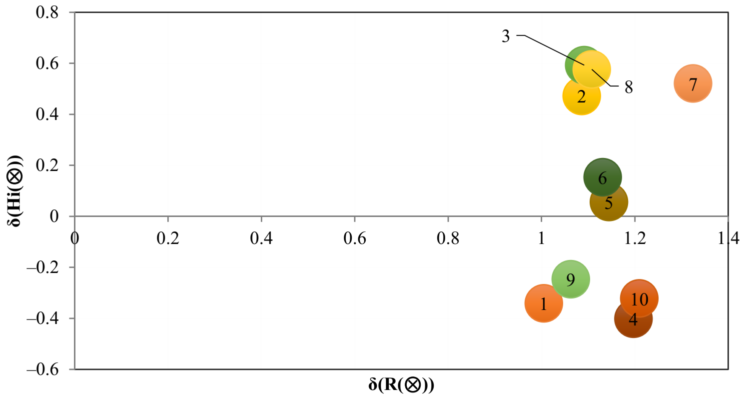
The parameters are listed from the input of the experts and parameters which represent the interactions (Step 1) and numerical value of the barriers are selected and the five grey linguistic number matrices depicted in Table S4 (see supplementary file) are converted into the three-parameter interval grey numbers that relate to it (Step 2). Direct relational metrices are gathered from the expert team to form the principal grey group metric (Step 3). Using the insight from the team, by using Step 4, at first the normalized matrix is figured out and subsequently the grey total relation matrix is calculated.

Finally, the total of the rows and columns are determined by using the Step 5. The overall prominence, $R_i(\varkappa)$ and net effect, $H_i(\varkappa)$ are computed by deploying the Step 5. By placing the $R_i(\varkappa)$ values along X axis and $H_i(\varkappa)$ values along Y axis of the barriers, all the barriers are plotted in Figure 1. Each barrier is represented with a colored circle. Thoi's diagram represents the cause-and-effect groups of barriers (Figure 2).

Following Step 6, the relative kernels $\delta(R_i(\varkappa))$ and $\delta(H_i(\varkappa))$ correspondingly, for each barrier are calculated and depicted in Table 2. And then the whitened total relation matrix is calculated (Step 6). The mean and standard deviation of whitened total relation matrix is found to be $\mu = 0.3859$ and $\alpha = 0.12293$, respectively. After that, $B_1 = \mu + \alpha = 0.5088$ and $B_2 = \mu + 2\alpha = 0.6317$ are calculated (Sun *et al.*, 2021). According to the Sun *et al.* (2021) if, $d'_{ji} < B_1$, the influence of b_i on b_j is not significant and can be ignored subsequently. If d'_{ji} falls in between, B_1 and B_2, subsequently, the impact of b_i on b_j is significant and represented as a continuous dotted arrow in the causal diagram in Figure 2. And, if $d'_{ji} > B_2$, the influence of b_i on b_j is strong and therefore depicted by dotted arrow in the casual diagram. Afterwards, by using the Step 7, the fitness value for each barrier is calculated. Table 2 displays all of the relative kernels in terms of overall prominence and the net influence of each barrier. And then the total fitness values of the system's 2^{10} possible configurations are found (Sun *et al.*, 2021).

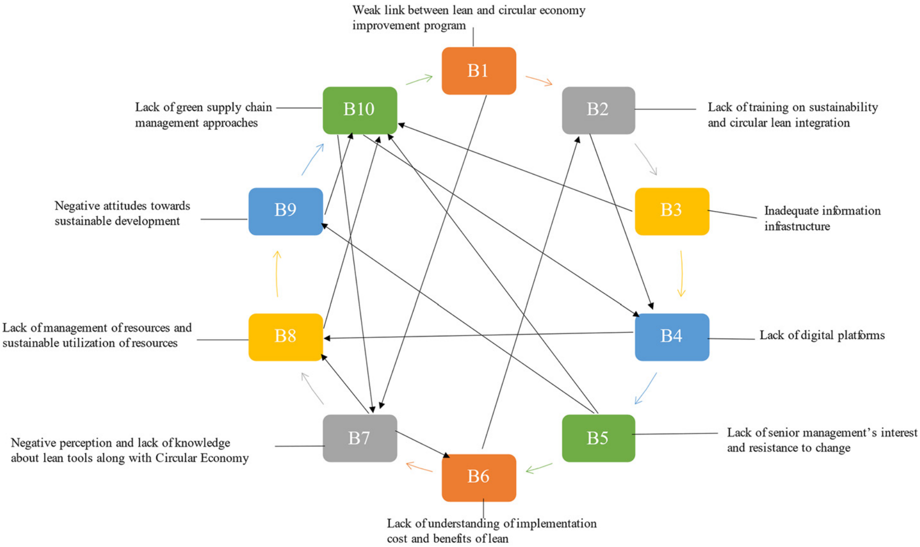
From the starting configuration (00000 00000) to the final configuration, Step 8 was used to locate the most effective means of overcoming the challenges and obtaining the ultimate configuration as (11111 11111). When starting at the original configuration (00000 00000), the route must first locate the initial obstacle to overcome (see Figure 3).

By overcoming barrier b_7 in the first phase, algorithm from Step 8 calculates the highest overall fitness value of 1.64. As a result, the first obstacle that must be encountered is b_1, and the configuration of the system shifts from (00000 00000) to (00000 01000). The algorithm then optimizes the second step based on the first, and by overcoming barrier b_8, the programme achieves the highest total fitness value of 3.61. As a result, the second barrier to



Source: Authors' own contribution

Figure 1.
The causal diagrams of the barriers



Source: Authors' own contribution

Figure 2. Causal interactions between the barriers

Barriers	$\delta(R_i(\varkappa))$	$\delta(H_i(\varkappa))$	$\delta^{\times}(R_i(\varkappa))$	$\delta^{\times}(H_i(\varkappa))$
B1	1.005128	−0.34053	0	0.060837
B2	1.086295	0.472152	0.089983	0.878606
B3	1.091544	0.592792	0.110005	1
B4	1.197196	−0.40099	0.903628	0
B5	1.144417	0.056073	0.863791	0.314842
B6	1.13094	0.15346	0.853619	0.359601
B7	1.324877	0.520795	1	0.637487
B8	1.107806	0.576458	0.915816	0.679595
B9	1.062704	−0.24603	0.87853	0.057392
B10	1.209638	−0.3219	1	0

Source: Author's own contribution

Table 2. Relative kernels, modified relative kernels of overall prominence and net effect of each barrier

be addressed is b_8, and the configuration of the system shifts from (00000 01000) to (00000 01100). The remaining optimization stages are carried out in the same way until the ultimate configuration (11111 11111) at position 10 is attained. Finally, the critical location of the best approach to overcome all barriers is determined and displayed in Table 3.

4.2 Discussion of the key findings

DEMATEL-NK system is applied to find out the optimal path for identifying and removing barriers, which is aimed to model the best pathway for implementing lean. After the necessary steps are done, the findings are discussed below:

The first barrier that needs to be addressed for the lean implementation is factor no. 7 – negative perception and lack of knowledge about lean tools along with CE. Due to a lack of awareness about the availability of lean tools and their subsequent use, the majority of

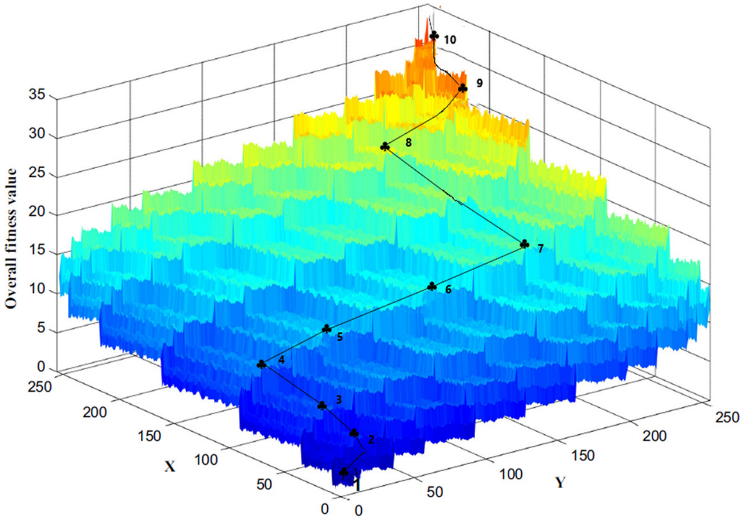


Figure 3.
The simulated optimized path for overcoming the barriers depicted on the 3-D fitness landscape

Source: Authors' own contribution

Table 3.
Optimal path for overcoming the barriers to implement lean manufacturing

Positions	Selected barrier	Configuration	Overall fitness value
1	B7	(00000 01000)	1.64
2	B8	(00000 01100)	3.61
3	B6	(00000 11100)	5.77
4	B5	(00001 11100)	7.12
5	B3	(00101 11100)	10.08
6	B10	(00101 11101)	13.51
7	B2	(01101 11101)	17.02
8	B9	(01101 11111)	22.14
9	B4	(01111 11111)	26.93
10	B1	(11111 11111)	32.27

Source: Authors' own contribution

current industrial procedures are not modified (Abu *et al.*, 2019). So, the systems are kept as they are and the quality improvement practice is being hampered. In addition, many of the management personnel are unaware of the terms CE and sustainability along with their potential benefit (Tan *et al.*, 2022). Hence, the authors identified the most impactful drivers and barriers that influence business leaders in their decision to transform their enterprises for engagement in the CE. So, management should change their perceptions towards the transition of proper LM to enhance CE in their firms.

The barrier which comes to the second to be identified is – lack of management of resources and sustainable utilization of resources that is factor no. 8. For the successful implementation of lean philosophy, highly motivated individuals are needed who can perform cross-functional activities with a sound technical knowledge blended with financial insight (Kabir *et al.*, 2021). Effective and efficient resource management and utilization is essential to achieving maximum sustainable lean management performance. Lack of these human resources must be treated in the second position.

Barrier no. 6 – lack of understanding of implementation cost and benefits of lean is selected to be dealt with in third place. There is a serious wrong perception about the usefulness of lean exists. Implementation of lean is a long-term process and it slowly but gradually makes a process better and better. So, it may seem that lean is not working or it is taking higher cost- which is not correct at all (Takeda-Berger *et al.*, 2021). These all hinders the implementation of LM.

Lack of senior management's interest and resistance to change – barrier no. 5 is to be addressed in place of no. 4. To successfully adopt LM, a company's attitudes must shift significantly, which can be difficult if the business is not prepared to address the changes. Many professionals along with the management are reluctant to change the existing system with the ongoing processes or machines (Khan *et al.*, 2020). So, it creates a serious issue in the path of lean application.

Barrier no. 3 that is inadequate information infrastructure comes in position no. 5. One of the main goals of lean is to tackle the existing waste and minimize it accordingly. Adequate information infrastructure can help to increase the efficiency of production networks and reduce waste generation as well (Polyakov *et al.*, 2021). Thus, companies should focus to build an adequate information infrastructure platform to enhance the operational excellence in their firms so that they can achieve the maximum outcomes of CE.

In position no. 6, lack of green supply chain management approaches comes, which is barrier no. 10. Firms should prioritize CE practices aimed at enhancing customer value while simultaneously preserving the environment (Gil-Lamata and Latorre-Martínez, 2022). Environmental supply chain management involves the engagement of the purchasing function in activities aimed at reducing, recycling, reusing and substituting materials. Thus, the concept of CE is aligned with green supply chain management (Al-khawaldah *et al.*, 2022). So, companies focus on green supply chain practices in their operational phase to achieve CE performance outcomes.

Barrier no. 2 – lack of training on sustainability and circular lean integration comes in position no. 7. A suitable sustainable lean training programme is one of the best ways to increase individual understanding of waste categories, lean concepts and their links to sustainable performance. Lack of lean understanding and shortage of lean consultants and trainers on sustainability, CE and lean make it very difficult to the proper application of lean tools (Rahim, 2017), thus making it an important barrier to be tackled with.

Barrier no. 9 – negative attitudes towards sustainable development – is the barrier to be addressed in the position no. 8. Companies have limited interest towards sustainable development programmes (Gil-Lamata and Latorre-Martínez, 2022). Without the proper zeal and interest of the authority it is near impossible to implement LM (Salman *et al.*, 2024). So, authority should be aware of the potential benefit of sustainable development in current era so that they can take necessary action to implement LM.

Lack of digital platforms which is no. 4 barrier comes in the position no. 9. Many industries have the necessity of implementing LM with the proper arrangement. Due to the lack of digital platforms, proper human resource along with trained experts in artificial intelligence (AI), internet of things (IoT), Big Data and so on, managements consider lean as a very difficult tool to implement (Patel *et al.*, 2022; Hamja *et al.*, 2022). Many industries have the necessity of implementing lean with the proper arrangement. But the above-mentioned perception makes them uninterested about LM.

In the last position, barrier no. 1 – weak link between lean and CE comes. Many companies set up their strategy or financial plan in such a way that there remains a little scope to implement regular improvement programme along with the process study activity

(Shammi *et al.*, 2022). The company's overall plan does not include any lean improvement programme along with CE enhancement so there is weak link between lean and CE improvement programme and strategy (B1). Many companies set up their strategy or financial plan in such a way that there remains a little scope to implement regular improvement programmes along with the process study activity (Čiarnienė and Vienažindienė, 2013). And for this reason, the chance of implementing lean tools in industries is minimized. In line with the previous findings (Deshmukh *et al.*, 2022), authors suggest that industry management should focus on building a strong link between improvement programmes of CE and lean implementation strategy in their industry.

5. Implications of the study

This study provided significant contributions to the LM area for both business professionals and academics in the following approaches:

5.1 Theoretical implications and implications for sustainable development goals

The research expands on the factors that influence proper and effective LM adoption for transition towards CE. Although, most of the previous studies have been analysed the implementation barriers of LM at the micro level and macro level. There has been little research in analysing the LM barriers for CE. This is the first study in the emerging country perspective in which LM barriers were identified for CE using DEMATEL-NK approach. The findings suggest that lack of knowledge management, lack of capability of management and utilization of the resources and understanding about the cost and benefits of the LM has most crucial impact on transition path towards CE. These identified factors have a strong influence on firm ability to transition towards CE.

This study provided significant contributions to the LM literature and resource base view in the following approaches. Firstly, this research advances to our understanding of LM application in emerging economies by identifying the key barriers that may hinder the firm ability to transition towards CE. The study represents the inaugural effort to devise an integrated conceptual framework through the application of the DEMATEL-NK model. Prior research has theoretically emphasized the key factors for a sustainable LM process for CE (Ciliberto *et al.*, 2021). This study also contributes to the green operations management literature. In this study, the authors extend the previous work on LM and CE (Kurdve and Bellgran, 2021) by exploring the key barriers that could slow down the transition towards the CE. The model proposed in this study allows us to understand what are the priority key barriers needs to overcome for successful transition towards CE. Secondly, the findings of this study contribute to the resource base view. Building on resource base view, our findings suggest that, human and technological resources could have a significant impact on the firm transition towards CE. Our findings highlight that, a firm in emerging countries must strike a balance between the effort on improving technological and human skills. Thirdly, our finding provides interesting insights to support and advance the United Nations' (UN) sustainable development goals (SDGs) in emerging economies. As illustrated in Figure 3, shows that "Negative perception and lack of knowledge about lean tools along with CE (B7)", "Lack of management of resources and sustainable utilization of resources (B8)", "Lack of understanding of implementation cost and benefits of lean (B6)" "Lack of senior management's interest and resistance to change (B5)" and "Inadequate information infrastructure (use of AI, IoT, Big Data Analytics) (B3)" are the top five barriers. As a result, the framework that has been provided in this study has the potential to be strongly related to the achievement of a number of SDGs that are pertinent. Our findings demonstrate that LM practices can directly contribute to the attainment of SDGs such as SDG 12 (Responsible

Consumption and Production), SDG 8 (Decent Work and Economic Growth), SDG 13 (Climate Action), SDG 9 (Industry, Innovation and Infrastructure), among others. Indeed, the implementation of LM practices enhances and optimizes production processes, while concurrently considering the impact on the environment, workplace conditions and natural resource utilization.

5.2 Managerial and practical implications

The preceding explanation highlights the findings, which will assist industrial firms in identifying the most critical, least significant and interrelated barriers. Administration members may now use this insight to be better informed about potential lean implementation barriers. Understanding these subjects would enable manufacturers, researchers and legislators to be successful in their efforts to eliminate barriers to lean projects. Finally, specialists in other areas of management who are also looking for new ideas in their work can track discoveries and ideas from published results. To enhance their lean principles, managers will be able to use this study as a reference. Industrial management may be able to better allocate resources by using the findings of this research to determine which variables are most important. The results of this article indicate that the lack of knowledge about suitable lean tools needed to be addressed first. It is also critical to have managerial support and financial resources to effectively implement lean methods. Those working in the manufacturing industry needs to confront issues in the category of causes that were described in the study. Organizations should be actively teaching people about lean's significance and advantages.

This research offers invaluable guidance for managers in industrial firms on overcoming key barriers to LM implementation, with a particular emphasis on enhancing sustainability and efficiency in production processes. The identification and prioritization of barriers – first among them being a lack of knowledge about lean tools and CE principles – highlight the critical need for targeted educational and training programmes to foster an informed and receptive organizational culture. Furthermore, the study underscores the importance of robust managerial support and strategic resource allocation, including financial and human resources, as essential elements for the successful adoption of lean practices. It also points to the necessity of adapting strategies to the unique challenges of each organization, suggesting that managers use the study's findings to tailor their approach to barrier management. Embracing technological advancements such as AI, IoT and Big Data analytics is identified as key to improving process efficiency and competitiveness. Additionally, by aligning LM practices with CE principles, firms can contribute to the achievement of several United Nations SDGs, including "Responsible Consumption and Production", "Decent Work and Economic growth" and "Climate Action". This holistic approach not only streamlines the transition towards lean and sustainable manufacturing but also supports broader environmental and socio-economic objectives, providing a clear pathway for managers and policymakers aiming to implement lean strategies effectively.

To better understand industrial managers who, want to use lean strategies, this research would be useful. To make the adoption of lean methods successful, those presently using lean and those planning to adopt lean should pay attention to these barriers. However, while various businesses have various levels and severity of barriers in the way of lean implementation, there are several main barriers that can be found in almost any organization.

6. Conclusions, limitations and future research directions

Despite the present literature's identification of numerous lean implementation barriers, their multi-dimensionality and complex interrelations have not been systematically addressed. Such interactions have not been used to determine which phases correlate to the associated barriers that should be focused to improve lean implementation framework development. In that case, a grey-DEMATEL-NK model has been proposed in this study, in which barriers are extracted and visualized in relation to their causes, and also uses an optimal path to find new methods of lean implementation for manufacturing industry in emerging economy. The authors' findings regarding the optimal path have useful implications for policymakers who seek to enhance LM. From the unique standpoint of prioritized barriers, the optimal path may be used as a strategic tool to implement lean by overcoming those priority barriers. By figuring out the optimal path that connects the challenges at each level, high-return solutions may be implemented more quickly.

Despite this, the study has several limitations, and there is still space for more investigation. Furthermore, the authors surveyed a number of categories of Bangladeshi professionals. In this case, the findings may vary somewhat from those gathered from a worldwide survey. More fruitful results may be attained if studies are performed on other lean implementation challenges, using regional or national contexts as examples. While this study provides a foundational understanding of integrating LM with the CE in emerging economies, we propose that future research should aim to encompass a broader spectrum of geographic locations. This expansion is crucial for validating the universality and adaptability of our model across different cultural, economic and environmental contexts. In addition, incorporating detailed case studies and real-world examples from these varied regions would significantly enrich the practical application aspects of our research. Such endeavours would not only strengthen the empirical basis of our findings but also offer deeper insights into the implementation challenges and opportunities faced by businesses globally.

To better visualize the study framework, researchers might use interpretative structural modelling, fuzzy cognitive mapping and analytical network methods. LM implementation strategy could benefit greatly from this formal analytical methodology. Many researchers now have the chance to perform more comprehensive study in this area.

References

Abu, F., Gholami, H., Mat Saman, M.Z., Zakuan, N. and Streimikiene, D. (2019), "The implementation of lean manufacturing in the furniture industry: a review and analysis on the motives, barriers, challenges, and the applications", *Journal of Cleaner Production*, Vol. 234, pp. 660-680, doi: 10.1016/j.jclepro.2019.06.279.

Abu, F., Saman, M.Z.M., Garza-Reyes, J.A., Gholami, H. and Zakuan, N. (2022), "Challenges in the implementation of lean manufacturing in the wood and furniture industry", *Journal of Manufacturing Technology Management*, Vol. 33 No. 1, pp. 103-123.

Agyabeng-Mensah, Y., Tang, L., Afum, E., Baah, C. and Dacosta, E. (2021), "Organisational identity and circular economy: are inter and intra organisational learning, lean management and zero waste practices worth pursuing?", *Sustainable Production and Consumption*, Vol. 28, pp. 648-662, doi: 10.1016/j.spc.2021.06.018.

Ali, S.M., Ahmed, S., Ahmed, H.N., Sharmin, A. and Rahman, R. (2022), "Reducing plastic pollutants through catalyzing consumer roles: a novel application of fuzzy total interpretive structural modeling", *Journal of Cleaner Production*, Vol. 335, p. 130327, doi: 10.1016/j.jclepro.2021.130327.

Al-Khawaldah, R., Al-Zoubi, W., Alshaer, S., Almarshad, M., ALShalabi, F., Altahrawi, M. and Al-Hawary, S. (2022), "Green supply chain management and competitive advantage: the mediating role of organizational ambidexterity", *Uncertain Supply Chain Management*, Vol. 10 No. 3, pp. 961-972.

Alkhoraif, A., Rashid, H. and McLaughlin, P. (2019), "Lean implementation in small and medium enterprises: literature review", *Operations Research Perspectives*, Vol. 6, p. 100089, doi: 10.1016/j.orp.2018.100089.

Awan, F.H., Dunnan, L., Jamil, K., Mustafa, S., Atif, M., Gul, R.F. and Guangyu, Q. (2022), "Mediating role of green supply chain management between lean manufacturing practices and sustainable performance", *Frontiers in Psychology*, Vol. 12, p. 810504.

Badhotiya, G.K., Sachdeva, L. and Soni, G. (2022), "Investigating and modeling interactions among manufacturing barriers due to Covid-19 pandemic: an interpretive ranking process", *International Journal of Industrial Engineering and Operations Management*, Vol. 4 No. 3, pp. 45-62, doi: 10.1108/IJIEOM-05-2022-0018.

Bashar, A., Akhtar Hasin, A. and Haq Adnan, Z. (2021), "Impact of lean manufacturing: evidence from apparel industry in Bangladesh", *International Journal of Lean Six Sigma*, Vol. 12 No. 5, doi: 10.1108/IJLSS-01-2020-0005.

Bayat, H. and Dadashzadeh, M. (2017), "The impact of organizational factors on implementation outcomes of lean manufacturing", *Journal of Business and Economics Research (JBER)*, Vol. 15 No. 2, pp. 33-44, doi: 10.19030/jber.v15i2.9932.

Bhadu, J., Bhamu, J., Singh, D. and Singh Sangwan, K. (2022), "An ISM approach for lean implementation barriers in labour intensive Indian ceramic SMEs", *International Journal of Productivity and Quality Management*, Vol. 35 No. 3, pp. 281-307.

Chaple, A.P., Narkhede, B.E., Akarte, M.M. and Raut, R. (2018a), "Modeling the lean barriers for successful lean implementation: TISM approach", *International Journal of Lean Six Sigma*, Vol. 12 No. 1, pp. 98-119, doi: 10.1108/IJLSS-10-2016-0063.

Chauhan, G. and Singh, T.P. (2012), "Measuring parameters of lean manufacturing realization", *Measuring Business Excellence*, Vol. 16 No. 3, pp. 57-71, doi: 10.1108/13683041211257411.

Cherrafi, A., Elfezazi, S., Chiarini, A., Mokhlis, A. and Benhida, K. (2016), "The integration of lean manufacturing, six sigma and sustainability: a literature review and future research directions for developing a specific model", *Journal of Cleaner Production*, Vol. 139, pp. 828-846, doi: 10.1016/j.jclepro.2016.08.101.

Ciliberto, C., Szopik-Depczyńska, K., Tarczyńska-Łuniewska, M., Ruggieri, A. and Ioppolo, G. (2021), "Enabling the circular economy transition: a sustainable lean manufacturing recipe for industry 4.0", *Business Strategy and the Environment*, Vol. 30 No. 7, pp. 3255-3272, doi: 10.1002/bse.2801.

Čiarnienė, R. and Vienažindienė, M. (2013), "Lean manufacturing implementation: the main chalenges and barriers", *Management Theory and Studies for Rural Business and Infrastructure Development*, Vol. 35 No. 1, pp. 43-49.

Deshmukh, M., Gangele, A., Kumar Gope, D. and Dewangan, S. (2022), "Study and implementation of lean manufacturing strategies: a literature review", *Materials Today: Proceedings*, Vol. 62.

Farias, L.M.S., Santos, L.C., Gohr, C.F. and Rocha, L.O. (2019), "An ANP-Based approach for lean and green performance assessment", *Resources, Conservation and Recycling*, Vol. 143, pp. 77-89, doi: 10.1016/j.resconrec.2018.12.004.

Gil-Lamata, M. and Latorre-Martínez, M.P. (2022), "The circular economy and sustainability: a systematic literature review", *Cuadernos de Gestion*, Vol. 22 No. 1, pp. 129-142, doi: 10.5295/CDG.211492MG.

Hama Kareem, J.A., Mohamad Al Askari, P.S. and Muhammad, F.H. (2017), "Critical issues in lean manufacturing programs: a case study in Kurdish iron and steel factories", *Cogent Engineering*, Vol. 4 No. 1, doi: 10.1080/23311916.2017.1386853.

Hamja, A., Hasle, P. and Hansen, D. (2022), "Transfer mechanisms for lean implementation with OHS integration in the garment industry", *International Journal of Productivity and Performance Management*, Vol. 71 No. 8, pp. 3534-3555.

Han, W., Sun, Y., Xie, H. and Che, Z. (2018), "Hesitant fuzzy linguistic group DEMATEL method with Multi-Granular evaluation scales", *International Journal of Fuzzy Systems*, Vol. 20 No. 7, pp. 2187-2201.

Hasan, M.M., Parven, T., Khan, S., Mahmud, A. and Yajuan, L. (2018), "Trends and impacts of different barriers on Bangladeshi RMG industry's sustainable development", *International Research Journal of Business Studies*, Vol. 11 No. 3, pp. 245-260, doi: 10.21632/irjbs.11.3.245-260.

Hasan, S., Khan, G., Hoque, M.R., Hassan, F. and Ahmed, N. (2022), "Lean practices in the Bangladeshi ready-made garments industry and global significance", *International Journal of Logistics Research and Applications*, Vol. 25 No. 3, pp. 309-327.

Haseli, G., Torkayesh, A.E., Hajiaghaei-Keshteli, M. and Venghaus, S. (2023), "Sustainable resilient recycling partner selection for urban waste management: Consolidating perspectives of decision-makers and experts", *Applied Soft Computing*, Vol. 137, p. 110120.

Jesson, J., Matheson, L. and Lacey, F.M. (2011), "Doing your literature review: traditional and systematic techniques",

Kabir, H., Maple, M. and Usher, K. (2021), "The impact of COVID-19 on Bangladeshi readymade garment (RMG) workers", *Journal of Public Health,*) Vol. 43 No. 1, pp. 47-52, doi: 10.1093/pubmed/fdaa126.

Karim, A. and Arif-Uz-Zaman, K. (2013), "A methodology for effective implementation of lean strategies and its performance evaluation in manufacturing organizations", *Business Process Management Journal*, Vol. 19 No. 1, pp. 169-196, doi: 10.1108/14637151311294912.

Kaswan, M.S., Rathi, R., Garza-Reyes, J.A. and Antony, J. (2023), "Green lean six sigma sustainability–oriented project selection and implementation framework for manufacturing industry", *International Journal of Lean Six Sigma*, Vol. 14 No. 1, pp. 33-71.

Khadanga, R.K., Kumar, A. and Panda, S. (2022), "A modified grey wolf optimization with cuckoo search algorithm for load frequency controller design of hybrid power system", *Applied Soft Computing*, Vol. 124, p. 109011.

Khan, M.A., Brymer, K. and Koch, K. (2020), "The production of garments and textiles in Bangladesh: Trade unions, international managers and the health and safety of workers", *South Asian Journal of Human Resources Management*, Vol. 7 No. 2, pp. 276-292, doi: 10.1177/2322093720944270.

Kumar, N., Kaliyan, M., Thilak, M. and Acevedo-Duque, Á. (2022), "Identification of specific metrics for sustainable lean manufacturing in the automobile industries", *Benchmarking: An International Journal*, Vol. 29 No. 6, pp. 1957-1978.

Kurdve, M. and Bellgran, M. (2021), "Green lean operationalisation of the circular economy concept on production shop floor level", *Journal of Cleaner Production*, Vol. 278, p. 123223, doi: 10.1016/j.jclepro.2020.123223.

Luthra, S., Mangla, S.K., Lopes de Sousa Jabbour, A.B. and Huisingh, D. (2021), "Industry 4.0, cleaner production, and circular economy: an important agenda for improved ethical business development", *Journal of Cleaner Production*, Vol. 326, p. 129370, doi: 10.1016/j.jclepro.2021.129370.

Martínez, L., Dinçer, H. and Yüksel, S. (2023), "A hybrid decision making approach for new service development process of renewable energy investment", *Applied Soft Computing*, Vol. 133, p. 109897.

Mathiyazhagan, K., Gnanavelbabu, A. and Agarwal, V. (2022), "A framework for implementing sustainable lean manufacturing in the electrical and electronics component manufacturing industry: an emerging economies country perspective", *Journal of Cleaner Production*, Vol. 334, p. 130169.

Maware, C., Okechukwu Okwu, M. and Adetunji, O. (2022), "A systematic literature review of lean manufacturing implementation in manufacturing-based sectors of the developing and developed countries", *International Journal of Lean Six Sigma*, Vol. 13 No. 3, pp. 521-556.

Mostafa, S., Dumrak, J. and Soltan, H. (2013), "A framework for lean manufacturing implementation", *Production and Manufacturing Research*, Vol. 1 No. 1, pp. 44-64, doi: 10.1080/21693277.2013.862159.

Naeemah, A.J. and Wong, K.Y. (2022), “Positive impacts of lean manufacturing tools on sustainability aspects: a systematic review”, *Journal of Industrial and Production Engineering*, Vol. 39 No. 7, pp. 552-571.

Okoli, C. and Schabram, K. (2010), “Working papers on information systems a guide to conducting a systematic literature review of information systems research”, *SSRN Electronic Journal*, Vol. 10 No. 2010, doi: 10.2139/ssrn.1954824.

Palange, A. and Dhatrak, P. (2021), “Lean manufacturing a vital tool to enhance productivity in manufacturing”, *Materials Today: Proceedings*, Vol. 46, doi: 10.1016/j.matpr.2020.12.193.

Panwar, A., Jain, R. and Rathore, A.P.S. (2015), “Lean implementation in Indian process Industries - Some empirical evidence”, *Journal of Manufacturing Technology Management*, Vol. 26 No. 1, doi: 10.1108/JMTM-05-2013-0049.

Patel, B.S., Sambasivan, M., Panimalar, R. and Hari Krishna, R. (2022), “A relational analysis of drivers and barriers of lean manufacturing”, *The TQM Journal*, Vol. 34 No. 5, pp. 845-876.

Polyakov, M., Khanin, I., Shevchenko, G. and Bilozubenko, V. (2021), “Constructing a model of national production system for building a circular economy for international trade involvement”, *Entrepreneurship and Sustainability Issues*, Vol. 9 No. 1, pp. 287-299, doi: 10.9770/jesi.2021.9.1. (17).

Puram, P., Sony, M., Antony, J. and Gurumurthy, A. (2022), “A conceptual framework for a systemic understanding of barriers during lean implementation”, *TQM Journal*, Vol. 34 No. 6, pp. 1469-1484, doi: 10.1108/TQM-09-2021-0261.

Rahim, M.M. (2017), “Improving social responsibility in RMG industries through a new governance approach in laws”, *Journal of Business Ethics*, Vol. 143 No. 4, pp. 807-826, doi: 10.1007/s10551-016-3131-9.

Salman, S., Ahmed, T., Taqi, H.M.M., Frederico, G.F., Dip, A.S. and Ali, S.M. (2024), “An integrated approach to explore the barriers to lean manufacturing in the context of the COVID-19 pandemic: implications for sustainability”, *International Journal of Industrial Engineering and Operations Management*, Vol. 6 No. 2, pp. 165-184, doi: 10.1108/IJIEOM-02-2023-0027.

Samadhiya, A., Agrawal, R., Luthra, S., Kumar, A., Garza-Reyes, J.A. and Kumar Srivastava, D. (2023), “Total productive maintenance and industry 4.0 in a sustainability context: exploring the mediating effect of circular economy”, *The International Journal of Logistics Management*, Vol. 34 No. 3, pp. 818-846, doi: 10.1108/IJLM-04-2022-0192.

Schulze, F. and Dallasega, P. (2023), “Barriers to lean implementation in engineer-to-Order manufacturing with subsequent assembly on-site: state of the art and future directions”, *Production Planning and Control*, Vol. 34 No. 1, pp. 91-115.

Shammi, M., Halder, P.K., Tareq, S.M., Rahman, M.M. and Kabir, Z. (2022), “From environmental impact assessment to strategic environmental assessment in Bangladesh: evolution, perspective, governance and challenges”, *Environmental Impact Assessment Review*, Vol. 97, p. 106890.

Shen, J. (2020), “An uncertain sustainable supply chain network”, *Applied Mathematics and Computation*, Vol. 378, p. 125213, doi: 10.1016/j.amc.2020.125213.

Silvestri, L., Gallo, T., Silvestri, C. and Falcone, D. (2022), “Integration of lean manufacturing in industry 4.0: an overview of tools and applications”, 2022 2nd International Conference on Innovative Research in Applied Science, Engineering and Technology (IRASET), 1-5, IEEE.

Sun, H., Dang, Y., Mao, W. and Luo, D. (2021), “Optimal path for overcoming barriers in developing china’s wind energy industry”, *Environmental Science and Pollution Research*, Vol. 28 No. 27, doi: 10.1007/s11356-021-12531-7.

Sun, H., Mao, W., Dang, Y. and Xu, Y. (2022), “Optimum path for overcoming barriers of green construction supply chain management: a grey possibility DEMATEL-NK approach”, *Computers and Industrial Engineering*, Vol. 164, p. 107833.

Takeda-Berger, S.L., Tortorella, G.L., Rodriguez, C.M.T., Frazzon, E.M.., Yokoyama, T.T. and Oliveira, M.A.D. (2021), “Analysis of the relationship between barriers and practices in the lean supply chain management”, *International Journal of Lean Six Sigma*, Vol. 12 No. 3, pp. 607-626.

Tan, J., Tan, F.J. and Ramakrishna, S. (2022), "Transitioning to a circular economy: a systematic review of its drivers and barriers", *Sustainability*, Vol. 14 No. 3, doi: 10.3390/su14031757.

Tissir, S., Cherrafi, A., Chiarini, A., Elfezazi, S. and Bag, S. (2023), "Lean six sigma and industry 4.0 combination: Scoping review and perspectives", *Total Quality Management and Business Excellence*, Vol. 34 Nos 3/4, pp. 261-290, doi: 10.1080/14783363.2022.2043740.

Tortorella, G.L., Narayanamurthy, G. and Thurer, M. (2021), "Identifying pathways to a High-Performing lean automation implementation: an empirical study in the manufacturing industry", *International Journal of Production Economics*, Vol. 231, p. 107918, doi: 10.1016/j.ijpe.2020.107918.

Ul-Durar, S., Awan, U., Varma, A., Memon, S. and Mention, A.-L. (2023), "Integrating knowledge management and orientation dynamics for organization transition from Eco-Innovation to circular economy", *Journal of Knowledge Management*, Vol. 27 No. 8.

Ulfy, M.A. (2020), "Rising Bangladesh: an Asian tiger", 10.13140/RG.2.2.28811.31525.

Yadav, G., Luthra, S., Huisingh, D., Mangla, S.K., Narkhede, B.E. and Liu, Y. (2020), "Development of a lean manufacturing framework to enhance its adoption within manufacturing companies in developing economies", *Journal of Cleaner Production*, Vol. 245, p. 118726, doi: 10.1016/j.jclepro.2019.118726.

Zhang, A., Venkatesh, V.G., Liu, Y., Wan, M., Qu, T. and Huisingh, D. (2019), "Barriers to smart waste management for a circular economy in China", *Journal of Cleaner Production*, Vol. 240, p. 118198, doi: 10.1016/j.jclepro.2019.118198.

Zhang, A., Venkatesh, V.G., Wang, J.X., Mani, V., Wan, M. and Qu, T. (2021), "Drivers of industry 4.0-Enabled smart waste management in supply chain operations: a circular economy perspective in China", *Production Planning and Control*, Vol. 34 No. 10, pp. 1-17, doi: 10.1080/09537287.2021.1980909.

Further reading

Chaple, A.P., Narkhede, B.E., Akarte, M.M. and Raut, R. (2018b), "Interpretive framework for analyzing lean implementation using ISM and IRP modeling", *Benchmarking: An International Journal*, Vol. 25 No. 9, pp. 3406-3442, doi: 10.1108/BIJ-07-2017-0177.

Lewis, M.A. (2000), "Lean production and sustainable competitive advantage", *International Journal of Operations and Production Management*, Vol. 20 No. 8, pp. 959-978, doi: 10.1108/01443570010332971.

Parmar, P.S. and Desai, T.N. (2020), "Evaluating sustainable lean six sigma enablers using fuzzy DEMATEL: a case of an Indian manufacturing organization", *Journal of Cleaner Production*, Vol. 265, p. 121802, doi: 10.1016/j.jclepro.2020.121802.

Supplementary material

The supplementary material for this article can be found online.

Corresponding author

Syed Mithun Ali can be contacted at: mithun@ipe.buet.ac.bd