Examining the Viability of Lean Production Practices in the Industry 4.0 era: An Empirical Evidence Based on B2B Garment Manufacturing Sector

Abstract

Purpose: The purpose of this research is to investigate the influence of the interrelationship between the deployment of Industry 4.0 (I4.0) technologies and the application of Lean Production (LP) practices on the degree of organizational Sustainability Performance (SP) enhancement of the Bangladeshi Ready-made Garment (RMG) sector.

Design/methodology/approach: Previously, researchers have utilized the Resource-based View (RBV) or Dynamic Capability View (DCV) to describe the interaction of resources and capacities (technologies, management practices, sustainability performance) to analyze their effectiveness. However, in light of several contemporary academic discussions, we contend that these organizational views are inappropriate for explicating sustainability performance. Hence, as the foundation of our theoretical framework, we used the Practice-based View (PBV), which is recommended as a useful window to evaluate the function of practices that are common and simple to emulate in execution. In order to test the theoretical framework and research hypothesis, we utilized Partial Least Square (PLS) analysis. For that, we carried out a systematic survey to collect data from 80 Bangladeshi RMG factories.

Findings: The results of this research imply that LP is a crucial factor in enhancing organizational SP. Moreover, the results also indicate that the adoption of I4.0 technologies along with LP can assist in delivering the lean objectives more efficiently and, therefore, the combined application of LP practices and I4.0 technologies play a significant role in enhancing organizational SP.

Originality: Though the present literature indicates the probable significant association between LP and SP or I4.0 technologies and SP, no study, within our knowledge, has empirically examined the combined impacts of correlation between LP and I4.0 on SP. This is also a unique study to apply the PBV theory to explain the organizational SP through the combination of common resources and technologies.

Keywords Lean production, Sustainability Performance, Industry 4.0, Structural Equation Modeling.

Paper type Research paper

1. Introduction

Sustainability has been considered a progressive notion that evolves as a result of adapting to fluctuating conditions (Wang et al., 2022). In the industrial setting, the concept of sustainability emphasizes the critical linkages between economic development, environmental challenges, and social difficulties (Ahmed et al., 2020). In this present day, sustainability has emerged as an urgent obligation for firms seeking to thrive in today's age because of the dangers posed by conventional industrial processes and laws enforced by collaborators and legislators (Getele et al., 2022). There has been increasing pressure on manufacturing industries due to the severe world financial and ecological circumstances, to combine diverse supply chain approaches for satisfying consumer expectations proficiently and dexterously while complying with ecological and social criteria (Ghaithan et al., 2021; Zhou et al., 2022). Due to the increased pressure from policymakers for enterprises to be ecologically and socially conscious, companies have recognized the fundamental importance of sustainable performance in gaining a business edge (Chowdhury et al., 2022; Nand et al., 2022). This has prompted both business executives and scholars to devise novel techniques for obtaining organizational sustainability performance (SP), which will help to boost business competitiveness. Several research works (Afum et al., 2021; Ali et al., 2021; Ghaithan et al., 2021; Wadood et al., 2022) have suggested that the implementation of Lean Production (LP) practices may enhance a company's environmental, social, and economic effectiveness.

LP practices have been widely embraced and diffused throughout several business areas. LP practices are a collection of approaches used to boost productivity as well as minimize production expenses (Ali et al., 2021; Hao et al., 2021), decrease environmental damage (Bibby and Dehe, 2018; Wadood et al., 2022), and boost social sustainability (Kamble et al., 2019; Eskandari et al., 2022). With respect to the environmental area, the contribution of LP practices in enhancing product durability and reducing stored components has resulted in lower pollution levels and a slower rate of resource diminution (Varela et al., 2019). In terms of the economy, LP practices deliver techniques that help to reduce waste, consequently boosting market volume and profitability (Afum et al., 2021). Regarding the social context, LP practices help to reduce waste and improve workplace health and security, hence enhancing societal living circumstances (Hao et al., 2021). Since LP practices are connected to process development, they aid in establishing a sustainable supply chain and operational effectiveness (Sajan et al., 2017; Eskandari et al., 2022). Numerous pieces of research (Kamble et al., 2019; Hao et al., 2021; Eskandari et al., 2022; Wadood et al., 2022) have been conducted to evaluate the links between LP practices and environmental and economic performance. But these studies contain a limitation. The influence of LP practices on organizational SP, considering concurrently environmental, social, and economic dimensions, has gained less emphasis in the existing studies. Manufacturing organizations must weigh up their ecological, social, and financial capabilities to succeed in the present dynamic marketplace (Barua, 2021). We consider this as an obvious research gap. In order to fill this gap, we propose our first research question (RQ1): *What are the impacts of LP practices on organizational SP, considering the environmental, social, and financial dimensions?*

However, despite the fact that LP has aided numerous businesses in reducing waste and improving a number of performance aspects, many businesses continue to struggle in their attempts to become lean businesses (Buer et al., 2018; Ali et al., 2021). Many businesses fail to examine the strategic alignment of LP techniques, attempting to deploy them in situations in which they are inappropriate (Shi et al., 2022). Others may find that the fundamental procedures of LP are insufficient and therefore do not suit the firm's operational needs (Agarwal et al., 2021). Furthermore, although they appear to be successful in the early LP adoption stage, many businesses struggle to maintain the inaugural enthusiasm of their LP initiative (Solke et al., 2022). In order to handle these difficulties, it is necessary to explore the offerings provided by information and communication technologies (ICT).

Lean Production (LP), which has its roots in the 1950s-era Toyota Production System, is not dependent on any type of ICT in its most basic form (Vanichchinchai, 2021). However, the desire to obtain more business competitiveness has placed pressure on firms to update their present manufacturing processes and procedures to more sophisticated heights by leveraging the technological advances of the Industry 4.0 (I4.0) era (Ali and Phan, 2022). The development of sophisticated I4.0 technologies has escalated the study interest toward how LP practices and I4.0 can potentially work together to produce greater performance. Several authors have provided summaries of the studies in this field, including Buer et al. (2018), Cagnetti et al. (2021), Ciano et al. (2021), Gallo et al. (2021), and Silvestri et al. (2022). Industry data also demonstrates that businesses may develop multidimensional solutions by incorporating the I4.0 with LP practices and get benefits from both (Valamede et al., 2020; Tortorella et al., 2021). Besides, the integration of LP practices with I4.0 adoption may aid in the removal or reduction of various hurdles to LP deployment. The accessibility of real-time information supplied by modernization and I4.0 technologies is valuable for understanding existing challenges via value stream mapping (VSM), an LP practice (Marinelli et al., 2021; Ali and Phan, 2022). Besides, the merging of I4.0 and LP will encourage the growth of lean philosophy in manufacturing industries and lower projected threats related to I4.0's high installation costs. Additionally, their collaboration might aid in reducing non-value-added activities and costs in situations where using LP practices alone is impractical. Furthermore, their integration might also help to reduce the deployment expenses of I4.0 technologies, which are more expensive to execute if LP practices are not advanced (Kamble et al., 2019; Hao et al., 2021; Wang et al., 2021; Wadood et al., 2022).

Unfortunately, research on the incorporation of I4.0 into other strategic techniques, such as LP, is currently limited. Numerous earlier articles (Tortorella et al., 2019; Rosin et al., 2020; Ciano et al., 2021; Gallo et al., 2021; Silvestri et al., 2022) aimed to investigate how various LP practices may profit from the adoption of a specific set of technology. Furthermore, several studies (Kamble et al., 2019; Rossini et al., 2019; Cagnetti et al., 2021; Silvestri et al., 2022) have proposed a favorable link between LP and I4.0, although the literature lacks empirical evidence of this kind of interaction. Thus, scientific confirmation of the interaction between I4.0 and LP practices is nascent, and further research is needed to properly comprehend if this association has an influence on organizational SP. We consider this as an obvious research gap. In order to fill this gap, we propose our second research question (RQ2): *What is the combined impact of I4.0 and LP practices on organizational SP?*

Many business researchers consider sustainability performance to be a dynamic capability. However, we dispute the appropriateness of the dynamic capability view (DCV) to the research field of this work on several grounds. Firstly, Dubey et al. (2022) conceptualized that the primary goal of DCV is to justify sustained competitive advantages, which has been considered a dependent variable in the DCV. However, in obtaining organizational SP, we have to focus on business unit performance, which is relevant to the assumption of the practice-based view (PBV). Secondly, Bag et al. (2021) highlighted that DCV requires inimitable, unmatched resources to gain sustained competitive advantages. But, LP practices and I4.0 are kinds of standard, publicly available practices which can clarify substantial performance variance. This also seems relevant to the PBV.

Therefore, in line with Dubey et al. (2022) considerations, we propose that the PBV is a much clearer and more inclusive substitute to the DCV for analyzing organizational SP.

Here, we also observe a significant research gap in the strategic management literature, supported by concepts other than DCV, in comprehending the links among LP, I4.0, and SP. In order to fill the above-mentioned research gaps, we developed a theoretical framework based on the PBV. The developed theoretical framework was then validated with survey data collected from 80 Bangladeshi RMG firms, deploying the partial least square-structural equation modeling (PLS-SEM) technique. This present study provides several significant theoretical contributions. Firstly, the application of the PBV concept in the operations management research field will help to analyze the degree to which LP can contribute to the organizational SP. Secondly, acknowledging the significance of the presence of I4.0 with LP practices to boost the organizational SP will enrich the literature regarding sustainable development. This study also provides some valuable managerial insights for industrial practitioners. Although Bangladesh is ranked as one of the leading manufacturers in textile industries, many companies have not fully entered the I4.0 era. In this situation, this research may assist policymakers in taking steps towards entering the I4.0 era, much like their competitors in other regions. Moreover, the results of this study can aid executives in understanding the influence of the presence of the I4.0 technologies along with LP practices to enhance the organizational SP. This will help policymakers and business executives to build strategies and policies to excel in I4.0 technologies and LP practices. Besides the theoretical and managerial contributions, this study offers several social contributions also. The use of advanced technologies of the I4.0 era and LP practices can improve working conditions and safety in factories. For example, smart sensors can monitor working conditions to ensure they are safe for employees, and robotic automation can take over dangerous tasks. In addition, the implementation of I4.0 and LP practices can lead to reduced resource usage, waste generation, and greenhouse gas emissions. As a result, the environmental damage caused by production might be reduced, resulting in a more sustainable society. The implications of this study regarding theoretical and managerial are discussed broadly in the discussion section.

The remainder of this work is organized as follows: A quick discussion of the background study is presented in Section 2. Section 3 outlines the establishment of the theoretical model and research hypotheses. Sections 4 and 5 present research procedures and data analysis, respectively. The following section represents an overall discussion along with the practical and theoretical implications of this empirical research. Finally, the concluding comments of this study are presented.

2. Theoretical Background

In this segment, at first, we analyze the PBV theory as the theoretical foundation of our study and its applicability in this study field. Then, we explore the existing literature on LP as an independent construct and SP as a dependent construct. We also review the existing literature on I4.0 as a moderating construct between the relationship LP-I4.0. In the next segment, we develop our theoretical framework and research hypotheses.

2.1 Practice-Based View (PBV)

The practice-based view (PBV) of strategy was proposed by Bromiley and Rau (2014) in response to a gap in the literature. This gap, according to Bromiley and Rau (2014), consisted of a lack of practical methods to help managers and businesses to improve business processes and performance. As a result, Bromiley and Rau (2014) propose the PBV as a substitute to the more long-standing Resource-Based View (RBV) of the firm, or its spin-off, the Dynamic Capability View (DCV). The PBV is more applicable to the field of supply chain management, as this is a more practically orientated discipline that needs a practically orientated theory (Bromiley and Rau, 2014).

As background, the PBV is based on the idea that even seemingly unimportant daily operations at any given company, may have an impact on the overall operational performance and efficiency (Bromiley and Rao, 2014; Dubey et al., 2022). Conversely, the RBV and DCV both attempt to describe how a company's assets or capacities result in better performance or contribute to the maintenance of outstanding performance (Bag et al., 2021; Awwad et al., 2022). However, Bromiley and Rau (2014) contend that the RBV and the DCV concepts are only appropriate to a minimum number of enterprises in a business. Consequently, those average enterprises generating minor but substantial development, do not match the applicability of these views.

Additionally, both RBV and DCV concentrate on the expository factors that produce competitive advantage (Bag et al., 2021; Lu et al., 2022). Nonetheless, the sustainability performance of an organization includes factors not only from an economic perspective but also from various environmental and social perspectives (AlShehail et al., 2022). Whilst the economic pillar of the triple bottom line is of paramount importance (Yang and Wang, 2022), the PBV acknowledges that the concept of sustainability is a multifaceted and complex construct. Supporting this position, Yang and Wang (2022) emphasize that Sustainable Supply Chain Management (SSCM) encompasses the entirety of an organizations supply chain and is therefore about managing sustainable practices across all organizational remits.

Whilst the incorporation of SSCM approaches into organizational strategic plans is now commonplace (Yang and Wang, 2022), the original notion by Bromiley and Rau (2014) still stands, and that is the need for practical techniques which can be applied by the managers and businesses themselves, to navigate the sophisticated concept of sustainability. The PBV recognizes that SSCM is the outcome of cooperation, experimentation, and experiential learning. This coupled with the significance placed on environmental, social, and economic norms in molding behavior, can then pave the way for the creation of strategic and efficient interventions to foster sustainability. The RBV and DCV approaches place a strong focus upon economic performance (Dubey et al. 2022), however, sustainability involves social and environmental success too. As such, the RBV and the DCV are inappropriate to explain sustainability performance. As such, sustainability management academics should focus on the common practices that might enhance the effectiveness of sustainable supply chain management, which can be achieved under the PBV approach.

Some scholars hold the perspective that sustainability management is only an extension of corporate supply chain management techniques (Alraja et al., 2022; Lu et al., 2022). However, other researchers argue that despite certain similarities, these two fields of management are vastly different regarding their objectives (Tiwari et al., 2020; Saha et al., 2022). Therefore, practicing sustainability management necessitates a different set of expertise. In contrast to corporate supply chain management, losses in sustainability management are not evaluated only in terms of higher operating costs or project delays. An absence of effective environmental measures can largely damage the environmental pillar of sustainability (Tiwari et al., 2020; Russo-Spena et al., 2022). Hence, the RBV or DCV concepts are not adequate for explaining sustainability management success, as economic performance is not the only measure.

Other studies have successfully applied the PBV approach to explain sustainability performance more accurately such as Kim and Lee (2015) highlighted the appropriateness of PBV to explain the sustainability of an organization. This study also proposes that the PBV theory is the most appropriate framework for this field of research.

2.2 Lean Production (LP)

The lean idea evolved from Japanese traditions (Afum et al., 2021). LP attempts to streamline the transfer of value by minimizing waste throughout the manufacturing process (Santos et al., 2020; Solke et al., 2022). In the concept of LP, waste encompasses everything which doesn't generate value for the final goods or services from the consumer's point of view (Sancha et al., 2020; Ufua et al., 2022). According to Möldner et al. (2020), LP is an approach that advocates the adoption of techniques such as Total Quality Management (TQM), Kanban, Kaizen, and Value Stream Mapping (VSM) to reduce waste and improve business performance. Womack et al. (1990) established an extensive concept of LP that encompassed the production system's efficiency and effectiveness matrix. The authors claim that in comparison to mass production, LP utilizes less amount of resources and time with respect to manual workers, production area, investment in machinery, and new product development hours. Also, it implies maintaining significantly less amount of the required inventory on-site, resulting in fewer mistakes and creating a larger and ever-expanding range of items. This concept covers the system's efficiency by integrating the association between input and output and the system's effectiveness by integrating the link between output and the business targets. Solke et al. (2022) stated that LP is not just a technique; it can be seen as a way of innovativeness and a holistic management perspective that inspires everyone in the organization to advance operations on a continual basis.

In addition to a holistic approach depending on a set of aims and principles, LP covers a range of strategies, tools, methods, and approaches that allow targets to be accomplished via the implementation of these applications (Fontenelle and Sagawa, 2021; Kovalevskaya et al., 2021). However, Valamede et al. (2020) discovered that no common LP application structure, as well as no specific LP implementation practices, methods, or approaches, exists there. Also, Wadood et al. (2022) claimed that although many scholars had sought to find out the primary LP practices, scholars could not agree on the significance of the practices. The practices vary greatly depending on the scholars' backgrounds. Because of such distinctions, scholars have proposed a variety of techniques under the same notion. Negrão et al. (2017) created a table with a summary of five categories of practices, including thirty-four measuring items for evaluating LP implementation, which they identified in the previous studies. Mayr et al. (2018) found twenty-four practices that they classified into eight categories in order to develop a tool to measure the extent of LP adoption in production industries. Pettersen (2009) used thirty-six LP practices, divided into six categories, to look at how these practices impact organizational sustainability in manufacturing industries. Shah and Ward (2007), undoubtedly one of the most cited publications on measuring LP implementation, conducted a literature study to develop an LP practices framework that included forty-eight measuring items of ten categories of constructs. Sanders et al. (2016) also used these forty-eight measuring items for their study by classifying them into four major categories. Because there is still a lack of broad consensus, the most often employed practices presented by multiple previous research have been summarized in Table 1 to conduct this study. While this research did not consider a few of the LP constructs reported in the literature, several were incorporated into associated constructs.

Table 1 Literature of LP constructs

Authors	LP constructs	Method
Shah and Ward (2007)	Supplier feedback, JIT, supplier relationship, customer participation, pull, continuous flow, TPM, employee participation, set up time minimization, process control	Confirmatory factor analysis (CFA)
Furlan et al. (2011)	JIT, TQM, and supply chain	CFA
Kaur et al. (2013)	TQM and JIT	Principle component factor analysis
Belekoukias et al. (2014)	Leadership, knowledge creation, TPM, JIT, VSM, customer focus	Conceptual
Sanders et al. (2016)	Just-in-time (JIT), TQM, Human Resource Management (HRM), and Total Productive Maintenance (TPM)	Scoring method
Bevilacqua et al. (2017)	Supplier management, product development, TQM, TPM, JIT	CFA
Negrão et al. (2017)	Waste elimination, JIT, customer relationship, workforce management, and TQM	CFA
Mayr et al. (2018)	Product design, customer participation, supplier relationship, JIT, flexibility, people management, optimization, and employee participation	Principle component factor analysis

Fontenelle and Sagawa (2021)	TQM, TPM, JIT, employee involvement, pull process, push process	Scoring method
Solke et al. (2022)	People management, knowledge creation, customer relations, customer feedback, JIT	CFA

Source: Authors own work

2.3 Industry 4.0 (I4.0)

The term “I4.0” denotes the digitized production process enabled by the effective collaboration of automation technologies such as big data, cyber-physical systems (CPS), and the internet of things (IoT) to production (Kamble et al., 2019). The fundamental goal of I4.0 is to enhance the effectiveness and flexibility of the production process (Hahn, 2020; Mersico et al., 2022). I4.0 is not just involved in the production process in an organization; it is concerned with the entire value chain (Frank et al., 2019; Ciano et al., 2021; Cho et al., 2022). Furthermore, it can monitor and sustain the whole lifecycle of processes and components related to the introduction of new businesses (Ali and Phan, 2022). Moreover, I4.0 has a substantial impact on the production gesture; technologies related to I4.0 can effectively replace the production planning process based on traditional forecasting methods with flexible self-optimization (Culot et al., 2020; Moeuf et al., 2020).

The notion of I4.0 is exceedingly complicated and broad, and there is no explicit definition of I4.0 provided in past studies (Ammar et al., 2021; Arromba et al., 2021). For example, Nara et al. (2021) emphasized that I4.0 reflects the capacity of industrial systems and elements to interact. Di Maria et al. (2022) claimed that the central aspect of I4.0 lies in the establishment of a network-connected smart process capable of self-optimizing operations. Besides, numerous scholars provided an overview of I4.0 focused on its integration feature, seeing I4.0 as a collection of related technological advancements aimed at expanding the automation of the organization (Matthyssens, 2019; Ciano et al., 2021; Pozzi et al., 2021).

The technological flow is an essential aspect of I4.0; a collaboration of smart and industrial technologies may truly facilitate horizontal and vertical convergence across the whole value chain of an organization (Cagnetti et al., 2021). However, no consensus on the catalogue of I4.0 implementing technologies has been established between scholars; researchers lack common agreement, and some discrepancies exist within the many literature disciplines (Ciano et al., 2021; Pozzi et al., 2021). Rüßmann et al. (2015), in their key work on the future scopes of I4.0 in manufacturing, proposed nine “foundations” regarding I4.0 technologies: Autonomous robots, IoT, Cloud computing, Cybersecurity, Big data, Horizontal and vertical integration, Additive Manufacturing (AM), Simulation, and Augmented Reality (AR). These identified foundations are also validated by many other I4.0-related works (Kamble et al., 2019; Culot et al., 2020; Ammar et al., 2021; Pozzi et al., 2021; Di Maria et al., 2022; Saha et al., 2022). Table 2 summarizes the key I4.0 foundations and technologies addressed in this research.

Table 2 Literature of I4.0 technologies

I4.0 foundations	Technologies	Sources
Autonomous robots	Synergetic robots Intelligent machines Automated Guided Vehicles (AGVs)	(Rüßmann et al., 2015; Pozzi et al., 2021)
IoT	RFID tags Sensors Real-time scanning	(Buer et al., 2018; Arromba et al., 2021; Saha et al., 2022)
Cloud computing	Cloud computing for data exchange Cloud computing for data analytics applications	(Matthyssens, 2019; Di Maria et al., 2022)
Cybersecurity	Virus scanners Signature scanner	(Frank et al., 2019; Culot et al., 2020)
Big data	Artificial intelligence Predictive analysis Prescriptive analysis	(Culot et al., 2020; Arromba et al., 2021; Saha et al., 2022)
Horizontal and vertical integration	Interconnection Data sharing	(Nguyen et al., 2018; Cagnetti et al., 2021; Di Maria et al., 2022)
AM	3D printing	(Ammar et al., 2021; Ciano et al., 2021; Saha et al., 2022)
Simulation	Product simulation Process simulation	(Buer et al., 2018; Cagnetti et al., 2021)
AR	Augmented reality Virtual reality	(Pozzi et al., 2021; Mersico et al., 2022)

Source: Authors own work

2.4 Sustainability Performance (SP)

The fundamental aims of manufacturing companies are to increase economic progress and improve social welfare inside the organization while preserving the environment for long-term success (Abreu et al., 2021; Kumar et al., 2022). Manufacturing organizations face diverse expectations from various stakeholders like vendors, regulatory authorities, consumers, and rivals that cannot be addressed by following a single purpose (Ahmed et al., 2020; Agrawal et al., 2022). To meet the various expectations, organizations must operate on all the dimensions of sustainability performance, namely economic, social, and environmental; all these dimensions are collectively known as the triple bottom line (TBL) (Elkington, 1998). TBL is widely considered the finest metric for assessing an industry's sustainability performance (Khan et al., 2021; Zhou et al., 2022). AlShehail et al. (2022) deemed economic and environmental dimensions to measure organizational sustainability performance in their study. Kamble et al. (2019) took all three dimensions of sustainability performance into consideration in their research to measure the performance across Indian manufacturing industries. The impact of LP practices can be effectively assessed across all three dimensions of business sustainability performance (Ghaithan et al., 2021; Rahman et al., 2022; Yang and Wang, 2023). In the framework of an I4.0 scenario, different I4.0 technologies have been proven to influence businesses' sustainability performance. However, empirical evidence supporting the influence of I4.0 on SP in varied companies is lacking in previous studies (Gupta et al., 2021; Nara et al., 2021; Patyal et al., 2022; Nand et al., 2022). Therefore, all three TBL dimensions are taken into consideration in this research.

3. Theoretical Model and Hypotheses Development

In this segment, we develop our theoretical research framework based on the PBV. Then, we develop a set of hypotheses that connect the LP construct with SP and also describe the mediating impact of I4.0 technologies on the relationship between LP and SP.

3.1 Lean Production (LP) and Sustainability Performance (SP)

LP is said to be an essential element for obtaining SP across all three dimensions in manufacturing industries (Ali et al., 2021; Kovalevskaya et al., 2021). Regarding economic dimensions, LP practices promote cost savings and a significant increase in profits, which lead an organization to increase production efficiency and market advantages (Hao et al., 2021; Yang and Wang, 2023). Besides, LP implementation enables value creation across all supply chain activities, increasing product availability and resulting in increased consumer satisfaction (Eskandari et al., 2022; Feng et al., 2022). In the environmental dimension context, it has been discovered that the advantages offered by LP practices, such as enhanced product excellence and decreased inventory status, are associated with lowering pollution levels (Kamble et al., 2019; Ali et al., 2021). One of the most popular LP practices, VSM, has been demonstrated to assist in environmental preservation by mapping resources, power, and groundwater through a systematic approach (Agarwal et al., 2021; Shi et al., 2022). The incorporation of LP with environmental science reduces the installation costs of different environmental development projects, marginal expenses linked to pollution control, hazardous chemical diffusion, and waste minimization (Hao et al., 2021). In terms of social sustainability, the combination of LP and high worker-engaged work behaviours have been shown to improve workplace safety (Hong et al., 2023). LP directed at equipment management, kaizen, and work conditions leads to lesser injuries, enhancing workers' health and safety (Wadood et al., 2022). Therefore, numerous scholars claimed a favourable association between LP and all three TBL dimensions (Sajan et al., 2017; Kamble et al., 2019; Afum et al., 2021; Wadood et al., 2022). Therefore, based on the arguments of the literature regarding the association between LP and SP, we aim to analyze the following hypothesis:

H1: LP has a positive impact on SP

3.2 Lean Production (LP) and Industry 4.0 (I4.0)

In recent times, the correlation between LP and I4.0 has received increased attention in business management studies. Lately, Scholars and professionals have begun to analyze how the joint adoption of both LP and I4.0 may considerably improve the organizational and economic performance of a business. Buer et al. (2018) emphasized that precise and in-time data exchange is crucial in order to implement the JIT and autonomation, two pillars of LP, effectively. According to them, precise inventory records are particularly crucial in lean supply chains since substantial buffers and backup stockpiles are removed. A digitalized supply chain can aid in accomplishing this by delivering rapid and precise information on stock levels and whereabouts (Silvestri et al., 2022). Autonomation is the process of providing machines intelligence such that they're able to discern between ordered and disordered processes on their own (Rossini et al., 2019). As a result, the machines will automatically halt when any type of fault is detected, ensuring that no flawed items are manufactured (Bag and Pretorius, 2020). The use of CPS in manufacturing, a pillar of the I4.0 era, provides this intellectual knowledge to machines and hence enables autonomation. Then, the machines will gain the capacity to notify irregularities more quickly, investigate the root causes, and conduct corrective actions autonomously (Tortorella et al., 2021).

Wang et al. (2021) stated that the adoption of I4.0 does not undermine the lean culture of an organization but instead serves to improve the maturity level of the lean operation. Gallo et al. (2021) argued that I4.0 would manifest in parts that must be incorporated into current lean structures, which will gradually enhance the adaptability of LP. In fact, the recognition of the appropriate incorporation of modern technologies with LP was demonstrated in the mid-1990 and was denoted as Lean Automation (LA) (Rossini et al., 2019). Lately, LA has received a lot of focus with the introduction of I4.0. Basically, some scholars argued that the adoption of I4.0 could be at odds with the fundamental tenets of simplification and continuous development, and minor gains could be achieved from LP, while others contend that both methods may be favorably associated.

For example, Valamede et al. (2020) noted that the current LA methods are often private solutions created to meet unique and particular firm demands that may contradict the typical high-tech and expensive I4.0 operations. Less dubious about this connection, Marinelli et al. (2021) stated that I4.0 programs are probably to be unsuccessful if they are not integrated into a suitable framework that considers crucial production regulations provided by LP. To put it another way, scholars contend that the widespread use of advanced ICT that undermines LP deployment could produce marginal returns, which may disappoint the management in respect of a higher degree of capital investment (Mayr et al., 2018; Rosin et al., 2020). In contrast, numerous scholars (Kamble et al., 2019; Cagnetti et al., 2021; Ciano et al., 2021; Silvestri et al., 2022) presented a more favorable perspective on this kind of link. They assert that the combined application of these approaches would enable businesses to surpass conventional constraints in a lean transition, resulting in significant outcomes.

Despite having various indicators, research that examines this connection generally shows a paucity of empirical data to back up their conclusions. As a matter of fact, Buer et al. (2018) highlighted that the literature on LP and I4.0 regarding their compatibility is still ambiguous. Moreover, they also called for more research on the combined impacts of this collaboration on the organization's various performance measures. Therefore, even though this association has inspired numerous research and real-world experiments, a lot needs to be explored in order to fully recognize its scope.

The preceding arguments not just encourage us to analyze the direct impacts of LP on SP but to analyze the compatibility of LP to improve organizational SP in the presence of I4.0. Therefore, we propose the following hypothesis:

H2: I4.0 can mediate the association between LP and SP

3.3 Control Variables

In order to fully explain the variance in different RMG firms, we included two additional contextual parameters as control variables. First, firm size (FS) has been widely highlighted as a crucial indicator of the proper establishment of a culture of continuous development, as highlighted by Shah and Ward (2007). We split firms into two separate groups for this criterion: firms with over 500 workers and those with fewer than 500, based on the suggestions of Tortorella et al. (2019). Second, technological intensity (TI) has been stated as a crucial component in facilitating the greater deployment of I4.0 technologies (Rossini et al., 2019). Therefore, we considered two groups for this criterion based on the intensity of the technological deployment of the firm: high and medium-high intensity, and low and medium-low intensity based on the suggestions of Tortorella et al. (2019).

Here, Figure 1 illustrates the suggested theoretical model applied in this research.

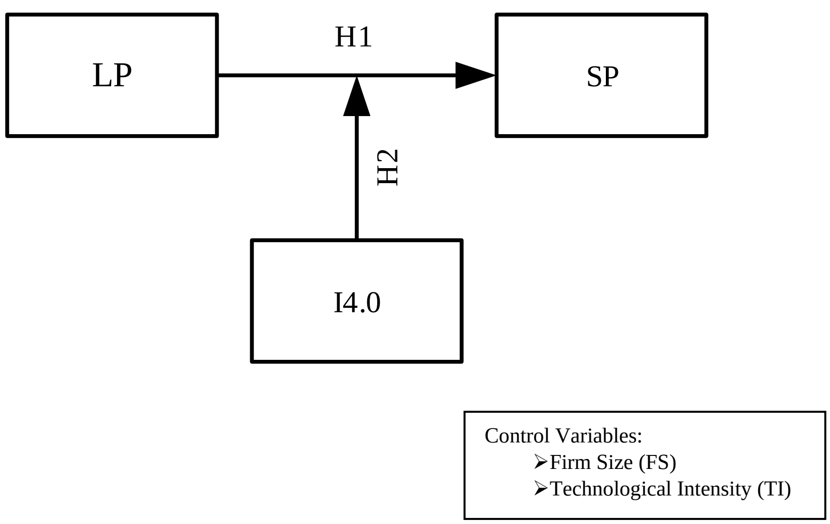

Fig. 1 Proposed theoretical model (Source: Authors own work)

4. Research Methods

A two successive mixed-methods technique was used in our research (Dubey et al., 2022). Step one of our research method involved an exploratory qualitative interviewing process in understanding the practices compatible with the RMG sector involved in enhancing the organizational SP. Additionally, the survey questionnaires utilized during step two are pre-tested.

In the following step, we carried out a cross-sectional survey. The data received from this survey was used to assess the independent and dependent constructs and proposed hypotheses.

4.1 Interviews and Survey Questionnaire Design

We carried out 12 semi-organized interviewing sessions in January 2022 with senior executives of the Bangladeshi RMG sector who are engaged in policy-making and the application of different management tools, as well as with academic scholars who have appropriate knowledge of research in the related field. The profiles of the participants of the interviewing sessions are demonstrated in Appendix A. Each interviewing session took, on average, 40-50 minutes. At the very first of the interview session, we requested the participants to express their perspectives about the application of LP practices and I4.0 technologies in enhancing the SP of the RMG factory, as well as the cumulative adaptability of LP and I4.0 technologies. The LP practices and modern technologies to reduce waste generation, reduce the environmental impact of industrial waste, improve health and safety issues of the employees, improve quality monitoring systems, and improve the data sharing and communication process were proved to be one of the most frequent replies. Then, we confirmed the developed primary hypotheses by questioning the importance of the adaptation of LP and I4.0 technologies to enhance all three dimensions of the organizational SP. Though few participants were unsure about the collaborative application of LP practices with I4.0 technologies, a broad consensus was found among the participants that the adoption of LP practices with the presence of modern technologies of the I4.0 era has great potential to achieve organizational SP at a higher degree.

In the second step, to construct a questionnaire for conducting the survey, we proceeded by reviewing the considerable literature mainly focused on the three primary themes- including lean production, industry 4.0, and sustainability performance- to find out key issues and constructed a preliminary measuring tool depending on the works of the previous scholars in the quality management field (Shah and Ward 2007; Sanders et al. 2016; Sajan et al. 2017; Bibby and Dehe 2018; Kamble et al. 2019; Rossini et al. 2019). From the result of the comprehensive literature study, the questionnaire has been categorized into three sections. Section one includes the basic demographic set of information (age, gender, designation) about the participants of the study and information about the control variables (firm size and technological intensity). Section two includes questions on lean production adaptation. This part aims to gain a sense of what the intended responders perceive about the impact of lean production in their organization. Section three includes questions on the extent of I4.0 technologies adaptation. The sole purpose of this part is to assess the perspectives of our targeted respondents. All participants were instructed to express their perceptions about the questions provided to them on a five-point Likert scale (where 1 to 5 points out to strongly disagree to strongly agree, respectively).

4.2 Sampling and Data Collection

Our experimental context is Ready-made Garment (RMG) factories engaged in the application of LP and advanced technologies of the I4.0 era in Bangladesh. The unit of investigation is RMG factories, and the survey questionnaire was developed for multiple respondents. Existing studies reveal that this investigation unit (RMG) gives a deep insight into the deployment of modern technology of the I4.0 era and management techniques that impact the organization SP (Talapatra et al., 2020; Barua, 2021).

We gathered the contact information of 145 RMG factories with the help of the Bangladesh Garment Manufacturers and Exporters Association (BGMEA), which is a national trade association representing Bangladeshi garment manufacturers (Talapatra et al., 2020). Next, we looked into the specifics of each RMG factory through an internet search and found 80 RMG factories that are utilizing the modern technologies of the I4.0 era and business management techniques like LP in improving the organizational SP.

Therefore, the sample size for our empirical analysis is 80 RMG factories, and from each factory, 4-6 employees, on average, were taken as survey respondents in this multiple-respondent survey analysis. The target participants were included from all levels of administration (top, middle, and bottom) who have appropriate knowledge about the deployment of the modern technologies of the I4.0 era and LP practices. Because of the Covid outbreak, just e-platforms (e-mails) were used to collect the necessary data. We surveyed between May 2022-September 2022 on Bangladeshi RMG organizations that are familiar with the application of the digital technologies of the I4.0 era. The random sampling technique was employed to collect the data. After two phases of reminder notifications, a total of 63 comprehensive and relevant replies were retrieved, having a response rate of 63/80=78.75%. This response rate is suitable enough to assess the proposed theoretical framework confirmed by the previous survey-based research (Gupta et al., 2019; Talapatra et al., 2020; Saha et al., 2022). Due to the budget limitation, no gifts or offerings were provided to the respondents. Table 3 shows the responder profiles along with the response percentage of every category. As depicted, top management accounted for 47.62 percent of the total respondents, while middle management accounted for 31.74 percent, and the rest went to bottom management.

Next, we checked non-response bias in the gathered dataset in two different manners. At first, we compared the replies of early and late waves of collected questionnaires to adjust for non-response bias (Armstrong and Overton, 1977). The overall sample was divided into equal-sized groups and ordered as per the weekdays on which replies arrived. Comparison analysis between the two groups was performed by conducting a t-test, which showed an insignificant difference at the level of a 95 percent confidence interval. Then, in accordance with the recommendations made by Iqbal et al. (2021), we approached 25 randomly chosen non-respondents and requested to provide a response to one question from each section of our theoretical framework. The resulting t-test shows no substantial disparities between responders and non-responders at the level of a 95 percent confidence interval. As a result, we may infer that non-response bias seems hardly a significant problem for this study.

4.3 Measures

Measures had been adapted from scales developed in previous studies to minimize scale multiplication. We employed a multi-item variable measurement for our suggested conceptual model to increase reliability, assure wider variety among survey participants and minimize measurement inaccuracy (Churchill, 1979). A total of thirty items (fifteen items of LP, seven items of I4.0, and eight items of SP) were taken into consideration for all the latent constructs to operationalize. Before including items in the finishing draft, each item was verified by five experts from different areas of industry and the academy to ensure that the content was legitimate. All the advice of the specialists has been taken into account in our study. The specialists' advice allowed the right phrasing to be used to enhance the queries. The measurements were originally developed in English and thereafter translated into Bangla by two specialists fluent in both English and Bangla. The Bangla edition was further translated back into English, and several differences between English and Bangla expressions were resolved (Brislin, 1970). A comprehensive list containing all the measuring items related to latent constructs considered in our study is presented in Appendix B.

5. Data Analysis

SEM and Factor Analysis (FA) are the two most extensively utilized approaches in previous studies for identifying structural relationships between latent variables (Mai and Liao, 2022). The bulk of scholars picked the first approach because of being more sophisticated and advanced than the other (Hair et al., 2014; Dubey et al., 2018; Gupta and Shankar, 2022). SEM is considered a multivariate approach that methodically combines factor analysis with path analysis which makes the technique more sophisticated (Ghaithan et al., 2021; Iqbal et al., 2021). Again, variance-based SEM and Partial Least Square (PLS) are the two most widely used approaches among different types of SEM approaches. PLS is primarily concerned with the analysis of variance (Hair et al. 2019). This study utilized WarpPLS, a statistical program to analyze the data using the PLS-SEM algorithm. This analysis is chosen for the subsequent reasons (Dubey et al., 2018; Gupta et al., 2019; Saha et al., 2022):

(i) This method has the ability to handle a large number of factors simultaneously
(ii) This technique can be very effective for a large and complex model to identify the existing relationships between constructs
(iii) This can be utilized in situations when predictability is critical.

Table 3 Sampling profile

Criteria	Genre	Reply (%)
Administration	Top	47.62
	Middle	31.74
	Bottom	20.64
Company size	Large (>500 personnel)	26.98
	Small and Medium (<500 personnel)	73.02
Technological intensity	High and medium-high	31.25
	Low and medium-low	68.75

Source: Authors own work

Silaparasetti et al. (2017) employed this method effectively to investigate the relationship between employee safety factors and employee behavior. Therefore, Iqbal et al. (2021) also utilized this technique to combine the manufacturing industry's innovation performance with entrepreneurial orientation.

5.1 Measurement Validation

The constructs used in this research are reflective. Hence, we calculated scale composite reliability (SCR) for each construct, factor loadings for each measuring item, and average extracted variance (AVE) for each construct to validate our model following Fornell and Larcker's (1981) guidelines, as shown in Table 4. We used factor loadings to check the validity of the items selected for the measurement model. Hair et al. (2017) stated that any items must possess a value of factor loading greater than 0.5 to be selected for the PLS-SEM analysis; otherwise, they should be deleted. The items which had shown a value of factor loading less than 0.5 were removed from the data set for final analysis. The final measuring items of our latent variables are shown in Table 4 with their individual factor loadings. Besides, the SCR and AVE values were determined to confirm the convergent validity of the constructs of the theoretical model. The values of SCR and AVE, presented in Table 4, also are all higher than the critical limit of 0.7 and 0.5, respectively, as per Henseler et al. (2016), indicating the convergent validity of our reflective constructs. We also calculated Cronbach's alpha value to ensure the measurement model's reliability and consistency. From Table 4, it can be noticed that all the alpha values exceed the critical limit (0.6), which indicates the high reliability and internal consistency of the measurement model (Molina et al., 2007).

Table 4 Measures of constructs and factor loadings

Construct	Items	Factor Loadings	Variance	Error	SCR	AVE	Cronbach's α
LP	LP1	0.67	0.45	0.55	0.97	0.72	0.86
	LP2	0.94	0.88	0.12			
	LP3	0.74	0.55	0.45			
	LP4	0.69	0.47	0.53			
	LP5	0.77	0.60	0.40			
	LP6	0.84	0.71	0.29			
	LP7	0.93	0.86	0.14			
	LP8	0.98	0.96	0.04			
	LP9	0.95	0.90	0.10			
	LP10	0.94	0.87	0.13			
	LP11	0.88	0.77	0.23			
	LP12	0.87	0.76	0.24			
	LP13	0.84	0.71	0.29			
	LP14	0.73	0.54	0.46			
	LP15	0.88	0.78	0.22			
	I4T1	0.77	0.59	0.41			
	I4T2	0.81	0.66	0.34			
	I4T3	0.90	0.81	0.19			

I4.0	I4T4	0.70	0.49	0.51	0.92	0.63	0.74
	I4T5	0.86	0.73	0.27			
	I4T6	0.74	0.54	0.46			
	I4T7	0.75	0.57	0.43			
SP	SP1	0.76	0.58	0.42	0.91	0.56	0.91
	SP2	0.70	0.49	0.51			
	SP3	0.78	0.61	0.39			
	SP4	0.77	0.60	0.40			
	SP5	0.71	0.51	0.49			
	SP6	0.71	0.51	0.49			
	SP7	0.70	0.50	0.50			
	SP8	0.84	0.70	0.30			

Source: Authors own work

After assessing the reliability, discriminant validity test was performed to address the discriminant issues of the structural model. We utilized two methods to ensure the divergent validity of the measures: Fornell and Larcker's (1981) criterion and HTMT (hetrotrait-monotrait ratio of correlations) as per Henseler er al. (2015). As per Fornell and Larcker's (1981) guidelines, we calculated the inner-correlation matrix and then supplemented the foremost diagonal components with the values of the square root of AVE. As can be seen in Table 5, the square root values of the AVE for each latent variable exceed the respective correlation coefficients in both rows and columns. Therefore, we can draw the conclusion that all latent variables show discriminant validity (Fornell and Larcker, 1981).

Table 5 Discriminant validity

	LP	I4.0	SP
LP	*0.85*		
I4.0	0.35	*0.79*	
SP	0.46	0.65	*0.75*

Note: The diagonal values in italic form represent the root-squared values of AVE

Source: Authors own work

We also used the HTMT criterion to check the discriminant issues among constructs. Henseler et al. (2015) suggested that a novel measure known as the HTMT ratio can be a superior evaluation indication of discriminant validity. To determine the HTMT ratio, we compare the average correlations of measures across latent variables (which measure various features of the model) to the average correlations of measures inside the same latent variable. According to Henseler et al. (2015), results from less than 0.85 indicate adequate discriminant validity; thus, the results demonstrate discriminant validity (see Table 6).

Table 6 HTMT values

	LP	I4.0	SP
LP	-	-	-

I4.0	0.574	-	-
SP	0.682	0.628	-

Source: Authors own work

Next, we looked at the issue of endogeneity before examining the research hypotheses of this study (Dubey et al., 2023). As per the suggestion of Kock (2019), we calculated the nonlinear bivariate causality direction ratio (NLBCDR). The analysis shows the value of NLBCDR is 0.75 (approximately), which is in the acceptable range (≥ 0.7). This result indicates that about 75 percent of path-related events accord to the assumptions of the conceptual model, and there is no statistical support that the conceptual constructs could be associated in both directions (Kock, 2019). This value also indicates that there is no causality issue in our proposed model (Dubey et al., 2023). We have further provided the values for model fit and quality indices supporting this conclusion in Table 7.

Table 7 Model fit and quality indices

Parameters	Estimate	Allowable if	References
APC	0.328, p<.001	p<.05	Dubey et al. (2022)
ARS	0.306, p<.001	p<.05	Dubey et al. (2022)
AVIF	1.199	0< AVIF≤ 5	Kock (2019)
Tenenhaus GoF	0.374	large >= 0.36	Tenenhaus et al. (2005)

Source: Authors own work

5.2 Hypotheses Testing

PLS-SEM was utilized to validate the proposed hypotheses in this research. As per Preacher and Hayes (2008), contrasting the SEM technique with regression analysis clearly reflects measurement error and enables hypotheses to be tested using latent variables rather than measured ones. Table 8 shows the findings of the path coefficient (β) and p-values of the PLS-SEM analysis. We found support for hypothesis H1, claiming that LP has a positive impact on SP, to be statistically significant (β=0.380, p<0.01). This result implies that the implementation of LP practices substantially contributes to an increase in SP of ready-made garments industries in developing countries like Bangladesh. The finding of our study provides empirical support for earlier studies' assumptions which argued that the application of LP practices could be a significant determinant in manufacturing organizations in enhancing the organization SP (Kamble et al., 2019; Afum et al., 2021; Hao et al., 2021; Eskandari et al., 2022; Wadood et al., 2022). In the case of control variables, we found that both control variables, firm size (FS) and technological intensity (TI), also have a significant impact on organizational SP. Here, the precise impact of FS and TI on sustainable supply chain performance and their relationships to other components remain attractive issues for further investigation.

Table 8 Hypotheses testing results

Hypothesis	Statement	Estimate (β)	p-value	Result
H1	LP → SP	0.380	p<.01	Accepted

Control variables				
Firm size (FS)	FS → SP	0.342	p<.01	Significant
Technological intensity (TI)	TI → SP	0.287	p<.01	Significant

Source: Authors own work

Then, to analyze the mediation impact of I4.0 technologies, the bootstrapping approach, also known as resampling, was employed since it has been demonstrated to be more capable of reducing type-I error at the time of evaluating direct and indirect correlations (Henseler et al., 2016). This study applied an SEM technique with bootstrapping (1500 resamples) and a 0.95 confidence interval to investigate the mediating role. At first, the direct impact of LP on SP was analyzed, excluding the mediator, to determine respective standard estimates (β) and level of confidence. The associations were then examined again, this time incorporating the mediator. In the case of full mediation, the direct impact (from LP on SP), excluding the mediator (I4.0), should be substantial; once the mediator (I4.0) is added, the direct impacts should be insubstantial, while the indirect impacts should be significant. On the other hand, partial mediation arises when all of the route outcomes suggest significant correlations with or without mediators. The findings of direct and indirect impacts are shown in Table 9, including the mediator and excluding the mediator. The standardized path coefficient (β) value was used to examine the mediating role of I4.0 on the association between LP and SP. Results show that all the correlations between LP and SP are significant, whether the mediator (I4.0) is present or not, which suggests that I4.0 partially mediates the association between LP and SP (p<.01).

Table 9 Mediation analysis

Mediation Analysis						
Hypothesis	Direct path	Direct effect	Indirect path	Direct effects, including mediation	Indirect effects	Result
H2	LP → SP	0.380, p<.01	LP → I4.0 → SP	0.354, p<.01	0.280, p<.01	Partial

Source: Authors own work

Further, we have demonstrated how well our conceptual framework can explain sustainability performance with the help of the co-efficient of determination (R^2). The identified value of R^2 implies that LP and I4.0 are powerful determining factors for obtaining SP. The value of R^2 also indicates that LP under the moderating effect of I4.0 technologies can explain nearly 31 percent (i.e., $R^2 = 0.31$) of the total variance in the organizational SP. That depicts a significant degree of the explanatory capacity of the structural model (Dubey et al., 2023). We also analyzed the effect size of constructs. The effect size is a measure used in statistics to quantify the size of the difference between two groups or the strength of the relationship between two variables (Cohen, 1988). As the β co-efficient values don't really assist in comprehending the amount to which the descriptive variables describe the outcome variables, the f^2 values must be reported to indicate the effect size (Cohen, 1988). From the PLS-SEM analysis, we discovered that the Cohen f^2 values in our instance are rather high. In addition, we presented the predictability values (Q^2) of the explanatory factors, which have already gained significant attention from scholars in PLS-SEM approaches (Chin, 1988). We noticed that the obtained value of Q^2 are substantially higher than 0.00, indicating that both LP and I4.0 are a powerful determinant of SP. This also explains the predictive accuracy of our model. The values of R^2, Q^2, and f^2 are shown in Table 10.

Table 10 Co-efficient of variation (R^2), predictability (Q^2), and effect size (f^2)

Construct	R^2	Q^2	f^2
SP	0.31	0.68	0.72

Source: Authors own work

6. Discussions

Our research has concentrated on investigating the influence of the interrelationship between the deployment of I4.0 technologies and the application of LP practices on organizational SP enhancement regarding the B2B garment manufacturing sector. We analyzed the combined impact of I4.0 technologies and LP practices on organizational SP to explore the viability of LP practices in the I4.0 era. Mainly two aspects sparked our attention on this subject. *Firstly*, the application of modern technologies of the I4.0 era has grown significantly among manufacturing organizations as well as service organizations to improve different performance measures (Ali and Phan, 2022; Awwad et al., 2022; Di maria et al., 2022). However, the impact of I4.0 technologies integrated with LP practices on SP has not been explored yet. Moreover, numerous scholars (Buer et al., 2018; Kamble et al., 2019; Silvestri et al., 2022) called for further analysis of the impact of I4.0 technologies integrating with different management approaches on various organizational performance measures. Hence, we established two research questions in our research to address the literature gaps and to clarify the scope of our study. In order to answer the research questions, we carried out our empirical study based on a survey design. We employed questionnaires and interviews as data collection techniques (see section 4). Then, analyzing the collected data using PLS-SEM analysis, we answered the research questions. In other words, we determined the impact of LP practices on organizational SP as well as the possible impact of LP practices with the presence of I4.0 technologies on organizational SP, which is discussed broadly in the following paragraph. *Secondly*, previous literature shows a trend of applying the RBV or DCV to explain the organizational SP (Tiwari et al., 2020; Dubey et al., 2022). However, LP practices and the modern technologies of the I4.0 era are two common practices that numerous firms have already introduced to enhance their organizational SP. These practices are not rare and not impossible to imitate for competitors. Moreover, enhancing organizational SP doesn't mean only economic growth; environmental and social growth is also prerequisites to enhance SP. Hence, the RBV or the DCV seems to be inappropriate conceptual frames for investigating the function of practices in obtaining SP. In such conditions, we contend that the previously described practice-based view (PBV) is particularly relevant in contrast with other views.

We utilized PLS-SEM analysis to evaluate our conceptual model and research hypotheses. The findings of the research present an insightful picture of the connections and relationships among the latent constructs LP, I4.0, and SP. Regarding the first hypothesis, the result offers empirical evidence that LP practices are significantly associated with organizational SP enhancement. This result implies that LP practices can help an organization boost its SP by improving working conditions through a higher level of safety, training, and incentives (Eskandari et al., 2022), optimal usage of resources to reduce waste and environmental impact (Afum et al., 2021), improving the quality of products and services provided to clients (Bibby and Dehe, 2018), and developing a long-term relationship with suppliers to reduce costs, wastage and improve quality (Wadood et al., 2022). Barua (2021) contended that aiming for greater environmental protection and worker safety is critical in manufacturing a standard-quality product and LP implementation facilitates the organizations to gain better environmental and labor safety, which will eventually strengthen the economic stands as well.

Our study also explores that the presence of I4.0 as a mediating factor amplifies the influence of LP practices on organizational SP. This suggests that adopting LP practices in the absence of I4.0 technologies adoption might not bring the ultimate desired enhancement regarding organizational SP as the digitalized attributes of the I4.0 era can enable an organization to quicken the real-time data-sharing process, which can drive the organizational SP. From the PLS-SEM analysis, it can be described that LP practices alone can explain approximately 31% of the total variance regarding SP in the presence of I4.0 technologies. That means the simultaneous adoption of LP practices and I4.0 technologies in the Bangladeshi RMG factories can take the level of SP enhancement to a substantially higher level. This result also suggests that LP practices and I4.0 technologies can perform together without demolishing any of these approaches' objectives, which clearly fades away the misconception of many scholars (Rosin et al., 2020; Valamede et al., 2020; Marinelli et al., 2021) regarding these association. In fact, LP practices and I4.0 technologies are intended to operate together to assist the RMG firms in minimizing waste and expenses where the implications of LP or I4.0 technologies alone seem difficult. For example, the use of big data, analytics, and the IoT may considerably increase the efficacy of supplier review and just-in-time delivery in boosting the sustainability of the B2B garment sector. Under an I4.0-LP regime, RMG firms can enable sophisticated sensors, configurable big data analytics for system improvement, modern communication infrastructure, and predictive technological capabilities.

Apart from these findings, this study also offers some theoretical and practical insights, which are discussed in the following sub-sections.

6.1 Theoretical Implications

The subject of I4.0 is acquiring popularity day by day in academia, as seen by the huge volume of calls for scholarly articles from prestigious publications such as the *Journal of Operations Management, Journal of Business and Industrial Marketing, Global Journal of Flexible Systems Management, Production and Operations Management, Journal of Cleaner Production, Sustainable Production and Consumption, Journal of Process Control,* etc. The significance of I4.0 technologies in sustainability management has been extensively studied in the existing literature (Nara et al., 2021; Agrawal et al., 2022; Saha et al., 2022). But, the area of collaboration of I4.0 technologies with other management techniques is still ambiguous. This study enriches the literature by analyzing the combined impacts of I4.0 technologies and LP practices on organizational SP enhancement. This is a one-of-a-kind study that provides an empirical investigation of the relationship between LP, I4.0, and SP. Previous research suggested the impact of either I4.0 or LP on SP (Nara et al. 2021; Agrawal et al. 2022; Shi et al. 2022; Feng et al. 2022). Nonetheless, neither of the works empirically examined the combined impact of LP and I4.0 on

SP. Besides, the application of the PBV in the sustainability management field adds a unique contribution to the literature. As discussed earlier, numerous previous scholars attempted to explain the SP based on the RBV or the DCV. But, in this study, we argued that the RBV or the DCV is likely to be inappropriate in this field of study, while PBV is more appropriate than the other business views based on various perspectives, which can add significant value to the current literature. Hence, in this study, we highlighted LP practices and I4.0 technologies as common, available, and imitable practices which is relevant to the concept of the PBV. Moreover, the research looked into the assumption that intermediary factors might provide critical insights into the link between management practices and organizational long-term sustainability performance. We found I4.0 adoption as a significant mediator in our analysis, offering more comprehensive views into the link between LP and SP and advancing the literature on modern technologies. Additionally, this research provides a set of verified measuring items for LP, I4.0, and SP, considering the viewpoints of Bangladeshi RMG industries. These measures have been empirically validated for reliability and validity tests, and with minimal adjustments, they might be used in comparable investigations in plenty of other business fields.

6.2 Practical Implications

This research provides significant insights for industry executives and experts engaged in adopting LP and I4.0 in the RMG sector. This study suggests that business administrators must admit the significance of achieving the organizational SP to sustain itself in the competitive marketplace. It also highlights the significance of LP practices in enhancing SP in all dimensions, as well as promoting the introduction of digital technologies. In order to achieve that, we developed a conceptual framework and provided empirical evidence to validate it. So, this study can help managers in the decision-making process regarding LP implementation. Besides, the results of this study can aid executives in understanding the influence of the presence of the I4.0 technologies along with LP practices to enhance the organizational SP. Organizations should explicitly define their goals toward SP and prioritize the various I4.0 technologies depending on their effectiveness in developing advanced production processes. The introduction of I4.0 technologies in RMG industries will turn the lean process into a digital lean process network connecting all the stakeholders of the organization, allowing the exchange of resources between the stakeholders. Moreover, the identified measuring items of the latent constructs can aid managers in analyzing their relative importance regarding their organizations. However, based on the results provided, managers should not rule out the possibility of additional constructs like TQM, innovation capabilities, etc., collaborating with I4.0 technologies to improve SP.

6.3 Limitations and Future Research Directions

Without a doubt, this study contains certain shortcomings. For instance, as I4.0 technologies are pretty new to Bangladeshi RGM industries, participants' understanding of I4.0 is inadequate. As a result, participants' responses to this section may not be centred on their knowledge in this sector. So, it is suggested that more research be conducted into the extent of I4.0 technologies deployment and challenges to their implementation in Bangladeshi industries. Besides, cross-sectional data were used in this study. However, this type of data is relatively easy and quick to collect; this type of data does not provide information about changes or trends over time. So, we encourage conducting future research based on longitudinal data to avoid such limitations. The sample considered for this research was confined to 80 RMG firms in Bangladesh. Despite the fact that the size of the sample was enough for assessment, a higher sample size might be beneficial to confirm the generalizability of this study. Moreover, this study suggests the joint implementation of LP and I4.0 technologies to enhance organizational SP. But, the barriers and challenges of the joint implementation of these practices are not listed here. So, further research can be conducted to analyze the barriers and challenges of joint implementation of LP practices and I4.0 technologies. Also, most of the measures of this study are subjective in nature. Though the validity and biases of the data are confirmed, in the case of subjective measures, there remains a possibility to arise issues regarding validity and biases (Dubey et al., 2023). So, we encourage researchers to use objective measures to avoid such issues. In addition, all the respondents regarding the data sample were from Bangladeshi RMG sectors, which confines the generalization of this research. Future research can be conducted to examine the impacts of I4.0 or LP on different types of manufacturing organizations in different locations to ensure the generalizability of the research. Further, this research may be expanded to include more measuring items of the construct variables.

7. Conclusion

In summary, the results of this research imply that organizational SP is more crucial for the RMG sector, and achieving SP is an even more complex procedure than previously stated in the literature. This study has provided comprehensive empirical evidence based on PBV and the association between I4.0 technologies and LP practices to achieve SP. We assume that the results of this research and the concerns it raises can spark future empirical works to better comprehend the minor differences in business resources, organizational capacities, and practices. Also, we hope that this study will motivate future scholars to apply the PBV vastly in the other field of operations management and supply chain management.

Appendix A. Sample for interviews

Participant	Gender	Industry type	Experience	Position
01	M	University	≥15	Professor
02	M	University	≥15	Professor
03	F	University	≥15	Professor
04	M	University	≥15	Professor
05	M	Garment	≥10	Operations Manager
06	M	Garment	≥15	Country Manager
07	M	Garment	≥15	Manager (Admin & HR)
08	F	Garment	≥15	Senior Manager (Production)
09	F	Garment	≥10	Assistant Manager (Quality)
10	M	Garment	≥12	Operations Manager
11	M	Garment	≥15	Senior Manager (Production)
12	F	Garment	≥10	Quality Controller

Appendix B. Measurement scales

Constructs	Items	Description	Adapted from
LP	LP1	Provided feedback on supplier's delivery and quality	Shah and Ward (2007); Sanders et al. (2016); Mayr et al. (2018); Valamede et al. (2020); Solke et al., (2022).
	LP2	Established strong relationships with key suppliers	
	LP3	Involvement of suppliers in designing new products	
	LP4	Official scheme for certifying suppliers	
	LP5	Commitment of suppliers to minimize the total annual cost	
	LP6	Locations of suppliers near the organization	
	LP7	Involvement of customers in the development of new product features	
	LP8	Pull production process in practice	
	LP9	Classification of products requiring the same operations	
	LP10	Practice of appropriate measures to reduce setup time	
	LP11	Substantial application of process control to limit process variation	
	LP12	Use of a fishbone diagram to analyze the root cause of any problem	
	LP13	Involvement of employees in conducting promotion and training programs	
	LP14	Maintenance of all equipment on a regular basis	

	LP15	Maintenance of all records regarding maintenance operations	
I4.0	I4T1	The company is either deploying or has already deployed big data	Culot et al. (2020); Ciano et al. (2021); Saha et al. (2022).
	I4T2	The company is either deploying or has already deployed a simulation technique	
	I4T3	The company is either deploying or has already deployed cloud computing	
	I4T4	The company is either deploying or has already deployed autonomous robots	
	I4T5	The company is either deploying or has already deployed IoT techniques	
	I4T6	The company is either deploying or has already deployed cybersecurity techniques	
	I4T7	The company is either deploying or has already deployed horizontal and vertical integration	
SP	SP1	Enhancing capability, capacity, and production measurements	Ahmed et al. (2020); AlShehail et al. (2022); Saha et al. (2022).
	SP2	Improved market positioning and holding Increased financial capabilities	
	SP3	Minimizing costs related to inventory	
	SP4	Management of wastes	
	SP5	Minimization of energy consumption	
	SP6	Minimization of carbon discharge	
	SP7	Improvements in safety measures in the working area	
	SP8	Improvements in the workplace environment	

Notes: LP- Lean Production; I4.0- Industry 4.0; SP- Sustainability Performance.

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