Exploring the influence of lean manufacturing and total quality management practices on environmental sustainability: the moderating role of quality culture

Abstract

Purpose: Organisations have released the importance of lean manufacturing practices (LMPs) and total quality management (TQM) in enhancing competitiveness. However, the implementation of LMPs and TQM becomes more complex when discerning the environmental sustainability position. The complexity stems from the fact that LMPs and TQM are more intricate due to cultural differences. Thus, this study tackles the aforementioned phenomenon by investigating the impact of LMPs and TQM on environmental sustainability moderated by quality culture.

Design/methodology/approach: A survey was distributed among small and medium enterprises (SMEs) in Jordan; thus, 315 valid responses were received. Partial least square structural equation modelling was used to analyse the data and test hypotheses.

Findings: The findings showed that environmental sustainability was significantly impacted by all the LMPs practices except Kanban and all the TQM practices except statistical process control. Moreover, quality culture significantly and negatively moderated the relationship between TQM and environmental sustainability. However, the influence of LMPs on environmental sustainability was not significantly moderated by quality culture.

Practical implications: This study has implications for policymakers in SMEs, supply chain managers and academics regarding the importance of LMPs and TQM systems for implementing environmental sustainability and the role of quality culture.

Social implications: The study provides guidelines for decision-makers on the pathways that enable them to sustain the environment to safeguard the natural ecosystem and natural resources for upcoming generations.

Originality: The originality of this study stems from the alignment of LMPs and TQM in enhancing environmental sustainability, taking into consideration the role of quality culture in SMEs, where previous studies failed short to investigate this phenomenon.

Keywords: Lean manufacturing; total quality management; environmental sustainability; quality culture; SMEs.

1. Introduction

Stakeholder concerns about harmful production activities have compelled companies to incorporate environmental initiatives into their supply chains (Huo *et al.*, 2019; Akhavan and Zvezdov, 2019; Al-Odeh *et al.*, 2021). Customer's desire for environmentally sustainable goods and services has increased after the World Commission on Economic Development introduced the term "sustainability" to the public domain in the 1990s (Wilburn Green *et al.*, 2015). Since then, several concepts have been used to refer to management practices that respond to this well-known pattern. With recent technological, societal, political, and environmental developments, a company's ability to gain and maintain a competitive edge has become a major challenge. In addition, customers' increased understanding of diminishing natural resources, emissions, and natural climate change is pushing businesses to implement environmentally sustainable activities and reduce their dependence on non-renewable energy, including fossil fuels, which can lead to disturbance in the ecosystem (Li *et al.*, 2018; Jum'a *et al.*, 2021; Al-Odeh *et al.*, 2021). Furthermore, as competition has increased, various operating methodologies, actions, and procedures have been developed to boost product quality, efficiency, and delivery times while lowering costs. Among these systems which have received particular attention are lean manufacturing practices (LMPs), total quality management (TQM), and supply chain management (SCM) (Nugroho et al., 2020). The two approaches of LMPs and TQM have been extensively developed and investigated to enhance companies' overall performance. This happens by eliminating waste from all operations, focusing on customer requirements, and serving them with quality products and services (Zelbst et al., 2010; Shokri and Li, 2020; Damert et al., 2021). According to Young (2009), efficient LMPs and TQM initiatives have enabled producers to adopt environmental sustainability practices.

Consequently, it is reasonable to suggest that, based on complementarity theory, when applied together, LMPs and TQM approaches can lead to a more favourable influence on environmental practices compared to the case when each approach is applied separately. In the 1960s and 1970s, the idea of LMPs emerged as a management technique aimed at adjusting needed inputs and production rates to market demand (Arjona Aroca *et al.*, 2020; Verma *et al.,* 2021). LMPs are the technique to eliminate all types of waste, enhance product quality, and maximize resource utilization (Khalfallah and Lakhal, 2020). LMPs manufacturing is considered a methodology that emphasizes minimizing/eliminating waste, constant quality improvement, and value maximization strategies in the manufacturing operations (Dowlatshahi and Taham, 2009). Since LMPs emphasize waste disposal while ensuring product consistency, it maintains the firm's environmental obligation. The term TQM emphasizes performance development and process control to produce a long-term, high-quality product that meets or exceeds consumer needs (Phan *et al*., 2019).

SMEs contribute to global economic development as they represent nearly 90 % of the businesses and represent almost 40 % of the GDP in emerging countries (The World Bank, 2021). However, SMEs are causing more than 50% of industrial pollution in different regions, such as the Asia-Pacific region, leading to environmental damage and emission (Williamson et al.,2006; Dey et al., 2020). Moreover, environmental destruction caused by SMEs will increase due to a lack of ability to improve performance and weak internal capability (Dey and Cheffi, 2013). Thus, the successful implementation of LMPs and TQM depends on employees' awareness of lean and TQM practices (Iranmanesh et al., 2019; Verma *et al.,* 2021). However, previous studies have concluded inconsistent results of the impact of LMPs and TQM on environmental performance (Hajmohammad et al.,2013; Iranmanesh et al., 2019). For instance, Abbas (2020) demonstrated that the TQM's components consisted of the Malcolm Baldrige National Quality Award- saved environment and natural resources (Abbas, 2020). Similarly, Green (2019) showed that TQM supports the implementation of a green supply chain that supports environmental sustainability (Green,2019). Nevertheless, the electronic industry in Thailand failed to implement TQM, and therefore it does not impact sustainable performance (Jermsittiparsert *et al.,*2019). In addition, Garza-Reyes *et al*. (2018) indicated that TQM practice such as Kaizen has a small impact on environmental results. Likewise, in some cases, the implementation of LMPs does not impact environmental sustainability because the environmental sustainability depends on a long term plan, while some companies adapted DMAIC (a six sigma tool) in the short term (Sreedharan and Sunder, 2018; McLean *et al.,*2017). Also, the absence of a proper system reduces the impact of LMPs on environmental sustainability (Belhadi et al.,2020). Moreover, the current understanding of the moderating role of quality culture on this phenomenon is limited in SMEs (Polyviou *et al*., 2019; Arsawan *et al*.,2020). It is not clear which practices of TQM and LMPs impact sustaining the environment, especially in SMEs. Also, the role of quality culture in moderating the impact of TQM and LMPs on environmental sustainability in SMEs is not clear (Nader *et al*.,2022). Antony et al.(2021) suggested future research to study the pre- lean implementation factors, such as lean barriers that contain developing the right culture. Psomas and Antony (2019, p.832) highlighted, "It is also worth comparing and contrasting the LM practices in the West with those in the East from cultural and leadership perspectives". Likewise, Jasti and Kodali (2015) encouraged LMPs studies in developing countries to get culture-independent results. Consequently, both academics and practitioners need empirical evidence on the importance of TQM and LMPs on environmental performance and the mediating role of quality culture in SMEs in different countries (Hines *et al.*,2020). Therefore, this study investigates the impact of LMPs and TQM on environmental sustainability moderated by quality culture in SMEs. Therefore, this study tried to find the answer to the following questions:

What is the impact of implementing both LMPs and TQM practices on environmental sustainability?

Does the quality culture play a moderator role in the impact of LMPs and TQM practices on environmental sustainability?

The result of this study is expected to provide empirical evidence- to academics and practitioners in SMEs -of the main TQM and LMPs that have the most impact on sustaining the environment and the role of quality culture in moderating this relationship. The paper has been organised into different parts. A study of similar literature comes first, followed by the formulation of hypotheses and a theoretical model. Then the research methodologies include data collection, study measurement, demographic characteristics of the respondents. The explanations of the research findings are then outlined. Discussion is the next part of the report, and it provides a straightforward overview of current observations and how they apply to previous research. After addressing the study's shortcomings and managerial implications, the study ends with a conclusion.

2. Literature review

The literature was divided into several sections. In section 2.1, the study demonstrated that there are individual connections between one or more of the main constructs in the study. In sections 2.2-2.5, the study proposed the main components of each construct based on the reviewed studies. Finally, in section 2.6, the study demonstrated the links between the main constructs to justify the conceptual model.

2.1 Previous research

Previous studies in the field of LMPs, TQM, and sustainability were reviewed (e.g. Abbas, 2020; Green *et al*., 2019; Mohammad Mosadegh Rad, 2006; Phan *et al*., 2019; Nguyen *et al*., 2018; Nugroho *et al*., 2020; Iranmanesh *et al*., 2019; Rupasinghe and Wijethilake, 2021; Sakakibara *et al*., 1997; Tasleem *et al*., 2019; Verma *et al.,* 2021). Sakakibara *et al*. (1997) investigated how LMPs practices and its infrastructure influenced manufacturing performance. The findings revealed that LMPs and infrastructure were both significantly related to manufacturing performance. Mohammad Mosadegh Rad (2006) assessed the effects and implementation of TQM and found areas such as leadership and management, process management, performance results, strategic planning and focus on customers, suppliers and material resources are influenced by TQM. Nguyen *et al*. (2018) found that four quality management practices significantly influence organisations' sustainability performance. These areas include product/service design, top management support for quality management, quality data and reporting, and continuous improvement. There was a significant relationship between LMPs, TQM, and practices pertaining to the green supply chain, as well as their combined impact on environmental sustainability (Green *et al*., 2019). Besides, Green *et al*. (2019) found that the direct influence of LMPs on environmental sustainability was not supported by practical evidence. The effect of TQM on firms' sustainability was found to be significant in the literature (Abbas, 2020; Green *et al*., 2019; Tasleem *et al*., 2019). Iranmanesh *et al*. (2019) examined the effects of quality culture on the link between lean manufacturing practices and sustainability. The findings showed that quality culture positively moderates the influence of process and equipment, as well as supplier relationships, on sustainability. The significant influence of TQM and LMPs production practices on the flexibility performance of manufacturing firms was also evident in prior research (Phan *et al*., 2019). Nugroho *et al*. (2020) observed that firm performance is significantly linked to the state of LMPs, TQM, and supply chain management. Approaches like LMPs deliveries, employee engagement, quality and environmental management are examples of lean practices that positively affect supply chain sustainability (Rupasinghe and Wijethilake, 2021). Thus, the reviewed studies demonstrated a connection between at least one or more of the main constructs of the study, including LMPs, TQM, environmental sustainability, and quality culture.

2.2 Lean Manufacturing Practices (LMPs)

As a manufacturing management concept that originated in Japan, JIT manufacturing involves making the right products and quantity, consistency, place, and time (Javadian Kootanaee *et al*., 2013). The American and Inventory Control Society (APICS) views LMPs as a production concept and a management strategy that aims to detect and eliminate all wastes on the one hand and to emphasize the quality improvement of productivity on the other hand (Chen, 2015). The primary aim of the LMPs is to constantly minimize and eventually remove possible sources of waste (Kumar and Panneerselvam, 2007; Bader *et al.,* 2020; Verma *et al.,* 2021). In general, companies that operate according to LMPs focus on growth and ensure spotting non-value-added processes to be dropped to decrease costs and increase efficiency and execution (Chen and Tan, 2011; Bader *et al.,* 2020). However, the practical application of LMPs is dependent on cooperation with the vendor in terms of inventory handling to increase product consistency and delivery process efficiency (Nugroho *et al*., 2020). Thus, LMPs consists of different tools; the most used tools in reviewed studies are summarized in Table (1). For instance, the kanban method is a modern ideology that plays a key role in the LMPs. The kanban system is an output management and inventory management system with several stages (Kumar and Panneerselvam, 2007). This method enables high production volume and power utilization with shortened processing time and work-in-process. Set up time reduction practice refers to the extent to which plants minimize startup time and lot sizes in production (Phan *et al*., 2019). The problems of excess inventory and substantial lot sizes lead firms to lot size reduction practices that simplify firms' manufacturing processes. Lot size-reduction practices reduce the stock cycle time by reducing setup time and manufacturing design for smaller lots of stock (Green et al., 2019; Bader *et al.,* 2020). Another term in LMPs is JIT scheduling. In JIT output scheduling, the manufacturer's main goal is to complete all required jobs as close to their due dates as possible, including assessing indicators, such as total weighted tardiness and total weighted earliness (Goldengorin and Romanuke, 2021). Existing evidence demonstrates that the careful implementation of JIT manufacturing leads to an increase in reliability and production, competitiveness, and a reduction in costs and waste (Javadian Kootanaee *et al*., 2013; Bader *et al.,* 2020). As can be seen from the reviewed studies in Table (1), authors attempted to cover LMPs that are mostly related to direct internal operations of manufacturing activities, focusing on one or two LMPs and others attempting to include more LMPs. As many authors have suggested, this study focused on four LMPs.

-----------------------------------Insert Table 1 Approximately Here------------------

2.3 Total quality management (TQM)

The concept of quality management (QM) provides greater value to consumers by constantly enhancing process performance is understood to share similar purposes with environmental sustainability (Molina-Azorín *et al*., 2009). QM consists of different tools; the most used tools in reviewed studies are summarized in Table (2). TQM is a method of controlling a company's overall effectiveness, performance, versatility, and competitiveness (Rad, 2006). It is a managerial approach involving all organisation members to improve operations, products, resources and the environment to promote greater customer and other stakeholder satisfaction (Yeng *et al*., 2018). After the 1980s, TQM has grown in popularity worldwide (Isaksson, 2006). TQM has become a key method commonly embraced by both manufacturing companies and service firms to improve company efficiency (Bajaj *et al*., 2018; Chiarini,2011). As a corporate management strategy, TQM enhances the efficiency of corporate management, increases competition, brings value to the customer, and provides companies with a competitive advantage (Lee *et al*., 2010). Businesses can incorporate a range of TQM constructs for effective quality management implementation. Customer focus, product design, statistical process controls are the TQM constructs we used in this study. Customer focus is expressed as the increasing interaction with the company and its clients, recognizing their needs, evaluating their satisfaction, and promoting programs that improve customer satisfaction (Anil and Satish, 2013). According to Goetsch and Davis (2014), "The consumer is the driver in a total quality setting." Since it is the starting point of every quality program, customer focus becomes a major factor in an organisation's performance (Pambreni *et al*., 2019). Product design in lean manufacturing leads to activities such as; multifunctional design teams, built for manufacturability, component modularization, and element standardization are also important considerations (Ahmad *et al*., 2003). The goal of product design activities is to make the product production process easier by reducing the quantity of content used in a product, which will improve the optimization of the assembly and manufacturing processes and, as a result, leads to better utilization of the company's resources (Iranmanesh *et al*., 2019). According to Yusr *et al*. (2017), process management entails maintaining a flawless product or service design, process monitoring, and quality development by self-inspection and automation, as well as ensuring transparent separation of process, ownership, and accountability. Thus, quality is a broad concept that can be defined differently. From the customer's perspective, quality is the extent to which a product performs its function and meets a customer's need. In contrast, from the producer's perspective, quality is the extent to which a product or service is produced correctly or the absence of defects or errors (Goetsch & Davis, 2014). This study concentrated on three areas of QM proposed by many authors and contributed to both viewpoints, as shown in Table (2).

-------------------------------------Insert Table 2 Approximately Here-------------------

2.4 Environmental sustainability

With rising stakeholder pressure for companies to be environmentally and socially conscious, businesses have recognized the strategic importance of sustainable performance in gaining a competitive edge (Wong and Wong, 2014; Jum'a *et al*., 2021; Al-Odeh *et al.*, 2021). , In addition, businesses have been inspired to increase their environmental sustainability and productivity as a result of the transition toward cleaner production processes and products (Caldera *et al*., 2017). Environmental sustainability refers to the process of promoting and conserving the natural environment and resources, controlling the waste, emphasizing cleaner processing, and rationalizing resource use (Hollingworth and Valentine, 2014; Jum'a *et al*., 2021). Environmental sustainability is concerned with organisations' efforts to safeguard the natural ecosystem and natural resources for upcoming generations (Lucas, 2010; Al-Odeh *et al.*, 2021). Simultaneously, environmental sustainability is also a competitive priority for businesses and must be balanced with their conventional growth and quality goals (Dieste *et al*., 2019). It also looks at the environmental effects of organisations' business operations, such as protecting the natural ecosystem from pollutants, effective use of natural resources, and natural heritage protection (Abbas, 2020). So, environmental considerations must be integrated into business culture and operational strategy at all stages by creating, manufacturing, handling, and disposing of products (Walker *et al*., 2014).

2.5 Quality culture

Influenced by the management system within organisations, culture is one of the major determinants that affect how work is done and how relationships are built in a company (Mann, 2015). It is the way we perceive and behave daily. Culture represents a company's personality and reflects the norms and beliefs of its people as well as how they act. In addition, organisational culture serves as an organisational asset aiding the effective execution of strategies (Zailani *et al*., 2015). Quality culture can be considered a corporate culture that contributes to workers' knowledge of lean processes and the actual work performed (Mann, 2015; Honarpour *et al.,*2018). Building and spreading a quality culture among employees and workers will facilitate the quick and efficient adoption of LMPs to achieve lean manufacturing goals (Iranmanesh *et al*., 2019). LMPs, as opposed to conventional industrial manufacturing, strives for higher quality manufacturing by eliminating waste products and reducing inputs (Nawanir *et al*., 2020). According to Atkinson (2010), it is difficult for lean practices to exist in a company where the organisational culture does not support it, and company culture dictates the effectiveness of lean or some other reform initiative. Cervantes (2006) analyzed organisations those adopted lean practices and found that those with a strong quality culture in the enterprise were more successful at implementing lean practices than those with a weak quality culture that only introduced lean practices on the factory floor.

2.6 Research Hypotheses and theoretical framework

2.6.1 LMPs and environmental sustainability

LMPs are process management initiative that aims to remove waste from procurement, manufacturing, and distribution processes while maximizing resource use (Inman *et al*., 2011; Verma *et al.,* 2021). It promotes the "zero concepts," which means achieving zero errors, zero queues, zero inventory levels, zero breakdown, and other similar aims (Kumar and Panneerselvam, 2007). In general, the LMPs are based on three basic principles: waste prevention, continual quality management, and encouraging workplace engagement in operations preparation and execution (Chan *et al*., 2010). Previous studies have found that LMPs and environmental protection are not only compatible but also complementary, resulting in a convergence that improves both environmental and business efficiency (Ali *et al*.,2020; Azevedo *et al*., 2012; Vinodh *et al*., 2011). The existing evidence argues that careful implementation of LMPs manufacturing is expected to increase production, competitiveness, and reliability and reduce costs and waste (Powell *et al*.,2017; Javadian Kootanaee *et al*., 2013; Bader *et al.,* 2020). In his study on a consortium of Australian organisations, Young (2009) found that successful leverage of internal LMPs capabilities promoted environmental sustainability initiatives. The findings of Zhu and Sarkis (2004) indicated that LMPs can enhance environmental efficiency. However, the association between environmental performance and green practices was poorer in companies that frequently used LMPs (Kalyar,2020). Finally, Klassen (2000) discovered that investment in LMPs practices is positively and substantially related to environmental efficiency. Based on the aforementioned discussion, the following can be hypothesized:

H1. Kanban positively influences environmental sustainability.

H2. Lot size-reduction positively influences environmental sustainability.

H3. Setup time reduction positively influences environmental sustainability.

H4. JIT scheduling positively influences environmental sustainability.

2.6.2 TQM and environmental sustainability

TQM focuses on reducing waste by eliminating inefficiencies in processes, while an environmental protection scheme is efficient at reducing noise, air emissions, and hazardous waste (Tasleem *et al*., 2018). The "zero defects" mission of quality management and the "waste reduction" philosophy of lean management goes hand in hand with the environmental management system's "no waste" goal (Molina-Azorín *et al*., 2009). Klassen and McLaughlin (1993) argued that environmental efficiency could be enhanced by adopting TQM and environmental management strategies. These strategies incorporate issues like product design, production, distribution, delivery, usage, and disposal processes. Successful TQM implementation has a major impact on green innovation in businesses, which is crucial for long-term sustainability (Li *et al*., 2018; Calic,2020).

Furthermore, as consumers continue to seek environmentally sustainable goods and services, TQM consumer focus would promote the inclusion of environmental protection as customer criteria, which can lead to the development of environmentally friendly goods and services (Green *et al*., 2012). Golicic and Smith (2013) expressed that TQM efforts tend to yield good results when applied to environmental matters. In their analysis of total quality environmental management, Garza-Reyes *et al*. (2018) concluded that there is a high level of compatibility and a positive relationship between TQM on the one hand and environmental sustainability activities on the other hand. Thus, the following hypotheses can be suggested:

H5. Customer focus positively influences environmental sustainability.

H6. Product design positively influences environmental sustainability.

H7. Statistical process control positively influences environmental sustainability.

2.6.3 Moderating effects of quality culture

According to Zheng *et al*. (2010), corporate culture is closely linked to organisational success, and it highly influences the efficiency of policy execution in companies. A culture of quality development in a company will promote the implementation of environmental sustainability strategies and values (Soltero and Waldrip, 2002). According to Womack and Jones (1997), eliminating waste and improving the production environment is not only possible with the use of lean manufacturing, but also requires a company-wide philosophy of performance development and waste reduction. As a result, incorporating a quality culture into the business would encourage LMPs, resulting in appropriate environmental awareness. TQM systems' success depends on whether the prevailing corporate culture is consistent with the principles and fundamental concepts suggested by the TQM discipline (Kujala and Ullrank, 2004). Therefore, it can be argued that the organisational culture would heavily influence the effectiveness of TQM as a systematic reform. In TQM implementation programs, organisational culture is a significant variance-causing element that either delays or enables the program's performance (Rad, 2006). So, the hypotheses stated below are formed following the above discussion:

H8. Quality culture significantly moderates the relationship between LMPs and environmental sustainability.

H9. Quality culture significantly moderates the relationship between TQM and environmental sustainability.

2.7 Theoretical framework

---------------------------------------Insert Figure 1 Approximately Here-------------------

3. Methodology

3.1 Data collection

SMEs sector is a pillar in low and middle-income countries where it plays a critical role in economic development and minimises poverty (Singh *et al*.,2010). SMEs contributes to more than 50% of national income (GDP) and are a key sector in creating job opportunities; thus, the central bank of Jordan supports financing programme relating to renewable energy, industry, tourism, agriculture, and information technology (Central Bank of Jordan, 2017). Moreover, SMEs is more affected than large companies in crisis. For instance, SMEs in Jordan suffers more than large companies during Covid -19 pandemic (Abu-Mater *et al*.,2021). Thus, this study collected evidence from SMEs sectors due to its importance and sensitivity.

The sampling strategy was a convenience sampling technique from SMEs in Jordan. The unit of analysis was the company level, where the general manager or the assistant general manager was the respondent from SMEs. Classifying companies as SMEs depends on Tewari *et al*.(2013), where small companies have employees from 10-49, and medium companies have employees from 50-249. A list of companies was received from the chamber of commerce; then, the SMEs companies were contacted through email to explain the aim of the study, followed by a phone call. Dörnyei (2007) highlighted convenience sampling used when there are specific criteria to select the sample. As a result, 1020 companies were contacted, while the questionnaire received was 350. The excluded questionnaires due to missing answers are 35, and the valid number of questionnaires is 315 (Table (3) shows the respondents' profiles). Thus, the actual return rate was nearly 31% which is higher than the suggested sample size, which was 200 or more (Hair *et al*.,2019). Moreover, the sample size of the study is sufficient, according to Tabachnick and Fidell (2007), who recommended the following equation to identify the sample size:

N> 50+ 8 M, where:

N= Sample size
M= number of independent variables

--------------------------------Insert Table 3 Approximately Here-------------------

3.2 Measurement instrument

The methodological choice of this study is a quantitative method to test hypotheses and generalize the research findings (Creswell, 2009; Hair et al., 2019). To do so, a survey was used as a research strategy to measure the trend and relationships in the data and obtain a high response rate (Creswell,2002). The survey was sent to 10 academics and experts to check its content validity (Yaghmaei,2003). The feedback suggested reducing the number of questions and simplifying some terminologies.

Measurement items related to the study constructs were sourced from the relevant past studies (See Table 4)—the items of LMPs practices and TQM (adopted from Green *et al*. (2019). The environmental sustainability and quality culture items were adopted from Iranmanesh *et al.* (2019).

The questionnaire was divided into two sections, where the first part included the demographic variables and the second part included the measurement items. The respondents were asked about the degree of their agreement on a 5 point Likert scale ranging from 1= strongly disagree to 5= strongly agree. The data was prepared for analysis by deleting the missing data and then entering and coding the answers for analysis.

--------------------------------------Insert Table 4 Approximately Here-------------------

4. Results

This part includes findings from the analysis of 315 datapoints using SPSS version 25 and SmartPLS version 3. This study utilized a partial least square approach to structural equation modelling (PLS-SEM) using SmartPLS software (Ringle *et al.,* 2015). The measurement and structural models were evaluated and validated as part of structural equation modelling. Consequently, the proposed research hypotheses were tested using structural model analysis. Smart-PLS uses graphical interfaces for variance-based structural equation modelling using the partial least squares path (Wong, 2013). Smart-PLS is primarily used in business research and can explain the relationships with few samples (Lu et al.,2010).

4.1 Descriptive statistics

As shown in Table (5), descriptive statistics display the mean, standard deviation, skewness, kurtosis and standard error of the latent constructs of the research. There are four latent variables in LMPs where lot size reduction had the highest mean score (M =4.21, SD = 1.017) and JIT scheduling had the lowest mean score (M = 1.8857, SD = .43671). Among the three practices of TQM, product design had the highest mean score (M =4.01, SD = .87451), and statistical process control had the lowest mean score (M = 3.18, SD = .76642). Moreover, the data is considered normal if the skewness is between -2 and +2 and the kurtosis is between -7 and +7. Table 5 demonstrates that skewness and kurtosis are within the range. As a result, the study's data is normally distributed.

--------------------------------------Insert Table 5 Approximately Here-------------------

4.2 Common method bias test

The Harman factor test was used to check for potential common method bias in the data. According to Podsakoff et al. (2003), if the covariance is greater than 50, the data contains common method bias. Moreover, the covariance explained by a single factor in this data is 35%, indicating no common method bias issue in the data, as shown in Table 6.

---------------------------------------Insert Table 6 Approximately Here-------------------

4.3 Test of Multicollinearity

In order to check multicollinearity (see Table 7). The values of variance inflation factor (VIF) and tolerance for latent variables were used. The values show that there is no multicollinearity since all of the VIF values are below 5 (ranging from 1.023 to 1.935), and the tolerance is greater than 0.10 (ranging from 0.517 to 0.978) (Hair et al., 2019).

---------------------------------------Insert Table 7 Approximately Here-------------------

4.4 Regression analysis

The heteroscedasticity test is part of the traditional assumption test in the regression model. Detecting the presence or absence of heteroscedasticities in data can be accomplished in a variety of ways, one of which is by inspecting the scatterplot graph on SPSS output. The Scatterplot graph between the predictive value of the independent variable is the working principle of the heteroscedasticity test with this method, as shown in Figure (2).

---------------------------------------Insert Figure 2 Approximately Here-------------------

According to the Scatterplot output, the spots appear diffused and do not form a distinct pattern. As a result, the regression model does not exhibit the heteroscedasticities problem. A popular misunderstanding in linear regression is that the outcome must be normally distributed, but the assumption is that the residuals are normally distributed. This assumption must be met for the p-values and t-tests to be valid. The P-P plot compares the observed cumulative distribution function (CDF) of the standardized residual to the expected CDF of the normal distribution to test residuals. The residuals are normally distributed, as shown in Figure (3).

---------------------------------------Insert Figure 3 Approximately Here-------------------

Regression demonstrates one-way causality and can only deal with observed variables, whereas SEM is meant to deal with both latent constructs and observable variables. SEM may be used to detect dual causation and bidirectional causality or effect. However, stepwise regression analysis was performed to emphasize the SEM results. Stepwise regression is the iterative development of a regression model step by step, which includes the selection of independent variables to be included in the final model. It entails progressively adding or removing potential explanatory variables and checking for statistical significance after each iteration.

The results of stepwise regression were consistent with the results of SEM, which showed that five out of seven variables significantly influenced environmental sustainability, including lot size reduction, customer focus, setup time reduction, JIT scheduling, and product design, as shown in Table 8.

--------------------------------------Insert Table 8 Approximately Here-------------------

According to Kline (2011) and Tabachnick et al. (2007), the essential first step in conducting the SEM model is confirmatory factor analysis (CFA). You should conduct this initially to ensure the measurement quality of all latent constructs in your structural equation model. The first step is to calculate the factor loadings of the latent construct's indicators (observed variables). Furthermore, developing this CFA measurement model allows you to test the convergent validity of your constructs. If your SEM model has more than one factor, conduct a CFA for all of the model's latent constructs within one measurement model to assess discriminant validity. Running goodness of fit statistics is one of the final procedures in analyzing the measurement model. Finally, the structural model is assessed.

4.5 Internal consistency and convergent validity

Measurement model analysis included assessment of both convergent and discriminant types of validity. In Table 9, convergent validity was ensured using the values of the factor loadings, Cronbach's alpha of internal consistency, composite reliability (CR) and average variance extracted (AVE). The findings showed that all the factor loading (>0.70) and AVE values (0.50) were above the recommended level and, thus, acceptable (Hair et al., 2019). Besides, Cronbach's alpha of internal consistency and composite reliability values also exceeded the recommended threshold of 0.70 and thus, the latent variables were highly reliable for structural model analysis.

--------------------------------------Insert Table 9 Approximately Here-------------------

4.6 Discriminant validity

When the square roots of the AVE are greater than the coefficients of correlation between all constructs, discriminant validity is achieved (Fornell & Larcker, 1981). The square root of the AVE was expressed by the diagonal values, while the off-diagonal values represented inter-construct correlations. All of the square roots of AVE values were greater than the correlation coefficients between all constructs, as shown in Table (10). As a result, the latent factors' discriminating validity was established.

--------------------------------------Insert Table 10 Approximately Here-------------------

4.7 Model fit

This study's model fit indices were checked using two fit measures: standardized root means square (SRM) and NFI. In order to determine model fit, criteria values should be within a certain range (the acceptable range for the SRMR index is between 0 and 0.08 and NFI values above 0.9 usually represent acceptable fit). Table (11) shows the SRMR and NFI values in relation to the criteria thresholds.

--------------------------------------Insert Table 11 Approximately Here-------------------

4.8 Assessment of structural model

Because PLS-SEM does not assume that the data is normally distributed, parametric significance tests cannot be used to determine the significance of coefficients such as path coefficients. PLS-SEM, on the other hand, uses a nonparametric bootstrap procedure to test the significance of estimated path coefficients. After checking the measurement model's validity and reliability, a bootstrapping was performed with 1000 subsamples to estimate the structural model in SmartPLS (Ringle *et al*., 2015). As illustrated in Figure (4), the arrows from the latent variables to environmental sustainability indicated the path coefficients. Besides, the r square value (0.479) inside the environmental sustainability suggests that the model explains around 47.9% variation in environmental sustainability.

--------------------------------------Insert Figure 4 Approximately Here-------------------

As illustrated in Table (12), the results of the structural model analysis showed that five out of seven variables significantly influenced environmental sustainability. Lot size reduction, customer focus, and product design significantly affected environmental sustainability at $p<0.01$. On the other hand, Setup time reduction and JIT scheduling had significant negative effects on environmental sustainability at $p<0.05$. Therefore, hypotheses H2, H3, H4, H5 and H6 were supported. Besides, customer focus had the largest effect on environmental sustainability (□ =0.290), indicating that when customer focus goes up by one standard deviation unit, environmental sustainability goes up by 0.290 standard deviation units.

--------------------------------------Insert Table 12 Approximately Here-------------------

Table (13) shows the effects of the quality culture as a moderator. Results showed that the effect of LMPs on environmental sustainability was not significantly moderated by quality culture. However, the effect of TQM on environmental sustainability was significantly and negatively moderated by the quality culture at $p<0.01$. Thus, hypothesis H9 was supported.

--------------------------------------Insert Table 13 Approximately Here-------------------

Figure (5) shows that quality culture positively moderated the relationship between LMPs and environmental sustainability, but the effect was insignificant. In other words, firms with high-quality culture and LMPs perform well in environmental sustainability.

--------------------------------------Insert Figure 5 Approximately Here-------------------

Figure (6) shows that quality culture negatively and significantly moderated the relationship between TQM and environmental sustainability. In other words, firms with low-quality culture but high TQM perform well in environmental sustainability.

--------------------------------------Insert Figure 6 Approximately Here-------------------

5. Discussion

The study aims to investigate the effects of LMPs and TQM practices on environmental sustainability and investigate the moderation role of quality culture. Part of the results was consistent with previous studies; other results differed from previous studies, while the remaining extended the current literature. The result showed that the implementation of both LMPs and TQM have a significant impact on environmental sustainability. The result further demonstrated that some LMPs significantly influence environmental sustainability, which is a lot size reduction. This result is partially consistent with recent studies that concluded the importance of LMPs such as JIT, DMAIC tool, and setup time reduction in improving environmental sustainability through minimizing raw material processing and packaging (Green et al.,2019; Abbas, 2020; Prakash and Potoski,2014). On the other hand, the results showed the negative impact of both setup time reductions and JIT scheduling due to lack of implementation among SMEs.

Unlike previous studies, the result of this study does not show any significant impact of Kanban practices on environmental sustainability. For instance, many studies demonstrated the importance of Kanban by reducing costs and avoiding overproduction, which enhances environmental sustainability (Muñoz-Villamizar *et al.,*2019; Green *et al.,*2019; Gupta, 2016). The reason behind the insignificant impact of Kanban on environmental sustainability in this study is due to the traditional implication of Kanban or the informal implementation of LMPs, which need to be modified in high variations situations and formalised to have an impact on environmental sustainability. Some studies suggested Kanban modification and aligning the practices with demand variation (Bai, 2019; Santos and Tontini; Gupta, 2016).

Furthermore, the result reveals that two TQM practices that are customer focus and product design, have a significant impact on environmental sustainability. Nevertheless, statistical process control does not significantly impact environmental sustainability. This is because of the weak link between the control process and environmental sustainability procedures.

There is no sufficient evidence about the role of quality culture in moderating the impact of TQM and LMPs on environmental sustainability in SMEs. The current study found significant negative moderating effects of quality culture between TQM and environmental sustainability. However, this finding is inconsistent with Iranmanesh et al. (2019), who found significant positive moderating effects of quality culture between lean practices and sustainability. Therefore, companies need to select a suitable leadership style, train their employees, engage and empower them to build a quality culture (Tortorella *et al.*, 2020; Zheng *et al.*, 2010; Gao and Low, 2014). The quality culture should have high-level collectivism, focus on humane orientation and a low level of assertiveness (Bortolotti *et al.*,2015). The rationale behind the negative impact of the quality culture is the weak quality awareness and implementation in SMEs as the sector depends on solving problems, not a systemised continuous improvement programme. Sawalha and Meaton (2012) stated that Arabic culture is characterized by low cohesiveness and internal integration. Therefore, there are no clear roles and responsibilities in some cases. Later, Alkalha et al.(2019) highlighted the pharmaceutical industry's weak quality culture- which is considered one of the best sectors in implementing quality management in Jordan- as the companies define quality as ‘’good manufacturing practices’’ only.

6. Conclusion

6.1 Brief overview of the research and findings

There is a vulnerability about the impact of LMPs and TQM on environmental performance in the extant literature, especially in the SMEs sector. Also, understanding the moderation role of quality culture is not clear. Therefore, this study provides an initiative to help SMEs face environmental sustainability challenges through LMPs and TQM practices moderated by quality culture while remaining competitive in the marketplace. This study observes significant associations among LMPs, TQM practices and environmental sustainability.

Moreover, a significant negative moderating role of quality culture has also been found between TQM practices and environmental sustainability. In other words, the effects of TQM on environmental sustainability are reduced in organisations with a quality culture. This is because of the weak quality awareness and quality implementation.

6.2 Implications for research

The results of this study provided sufficient evidence of the impact of TQM practices and LMPs on environmental sustainability in SMEs. The previous studies showed inconsistent results, and few investigated the effect of TQM practices and LMPs on environmental sustainability in SMEs. Moreover, this study highlighted pathways that lead to enhanced environmental sustainability by identifying LMPs and TQM practices that positively and negatively influence environmental sustainability.

This study shed light on building quality culture in SMEs as the results demonstrated the insignificant quality culture role in moderating the impact of TQM and LMPs on environmental sustainability. The reason behind the insignificant role of quality culture is the lack of quality awareness in SMEs that focus on short term improvements.

Furthermore, in a research context, this study emphasizes the importance of performing additional research that improve understanding of the role of quality culture in the implementation of LMPs and TQM practices. Furthermore, replication of this study in different situations and countries might contribute to improving environmental sustainability performance in SMEs and demonstrating the most practicable strategies that can be used to preserve the environment.

6.3 Implications for practice

The results of this study can be used in an economic and commercial contexts. Improving environmental sustainability in SMEs requires an initial investment, but they will be able to save money over time by prioritizing LMPs and TQM practices that achieve economic and commercial objectives. According to the findings of this study, LMPs and TQM practices such as lot size reduction, setup time reduction, JIT scheduling, customer focus, and product design should be integrated into the strategic plans of SMEs in order to increase operational efficiency and minimize costs.

Furthermore, in a teaching context, this research proposes that courses related to quality operations in connection to environmental sustainability should be incorporated in university programs, particularly for all engineering and management degrees. This will increase knowledge of quality culture and environmental sustainability practices, which will serve dual purposes in saving money and the environment for SMEs, and will eventually impact governmental policy addressing greening programs in SMEs.

Hence, the findings help SMEs' decision-makers plan the implementation of LMPs and TQM to enhance environmental sustainability. Moreover, this study focuses on the critical role of building a quality culture to facilitate LMPs and TQM practices.

Moreover, this study has implications for managers, practitioners and policymakers in various ways. Among the three significant practices of LMP, setup time reduction and JIT scheduling are negatively related to environmental sustainability. Therefore, supply chain managers and policymakers should be conscious of the negative effects of these two practices while building environmental sustainability. On the other hand, lot size reduction practices highly and positively influence environmental sustainability. Thus, practitioners should prioritise reducing lot size to improve environmental sustainability. The results of TQM practices also have implications for managers. As customer focus has the highest effect on environmental sustainability compared to the other practices of TQM, supply chain specialists should emphasize customer focus practices across the organisation to ensure environmental sustainability through TQM. Finally, the result showed a negative moderation impact of quality culture due to weak awareness of good quality and lean implementation. Therefore, decision-makers need to focus on building a suitable culture that supports quality and lean implementation to sustain the environment.

Finally, this study may have an impact on society by increasing public and government pressure on SMEs to adopt LMPs and TQM practices that lead to improved environmental sustainability performance. As long as LMPs and TQM practices can be implemented in a feasible manner by SMEs, public attitudes toward environmental sustainability implementation should be stronger and more effective, which will eventually reflect on the country's standards of quality of life in terms of products, environment, and health issues.

6.4 Limitations and future studies

Despite the theoretical and practical contribution, this study has some limitations that can open opportunities for future studies. Firstly, this study measured the impact of LMPs and TQM on environmental sustainability moderated by quality culture in SMEs in Jordan. Thus, this might impact the result's generalizability to other companies' sizes and in other countries. However, we are confident that results can be extrapolated to other SMEs. Therefore, future studies are advised to conduct this study on other companies sizes, such as large companies and other countries. Secondly, this study measured LMPs and TQM using certain constructs.

Consequently, future studies can consider LMPs and TQM practices with other constructs not considered in this study, such as agile manufacturing, operational performance, and customer satisfaction. Thirdly, the study showed some negative results, such as the negative impact of setup time reduction and JIT scheduling on the environment statistically sustainably and the negative moderation impact of quality culture. Therefore, future studies may qualitatively investigate the reasons behind these negative results. Fourthly, this study collected cross-sectional data, limiting measuring respondents' answers over time. Thus, future studies are suggested to collect longitudinal data.

Reference

Abbas, J., (2020). Impact of total quality management on corporate green performance through the mediating role of corporate social responsibility. *Journal of Cleaner Production*, 242, p.118458. https://doi.org/10.1016/j.jclepro.2019.118806.

Abu-Mater, W., Afifa, M.A. and Alghazzawi, M., (2021). The Impact of COVID-19 Pandemic on Small and Medium Enterprises in Jordan. *Journal of Accounting, Finance & Management Strategy,* 16(1), pp.129-149.

Ahmad, S., Schroeder, R.G. and Sinha, K. K. (2003). The role of infrastructure practices in the effectiveness of JIT practices: Implications for plant competitiveness. *Journal of Engineering and Technology Management*, *20*(3), pp. 161–191.

Akhavan, R.M. and Zvezdov, D., 2019. Addressing sustainability information needs along supply chains. Sustainability Accounting, Management and Policy Journal, 12(4), pp 643-666.

Ali, Y., Younus, A., Khan, A.U. and Pervez, H., 2020. Impact of Lean, Six Sigma and environmental sustainability on the performance of SMEs. *International Journal of Productivity and Performance Management*,70(8), pp. 2294-2318

Alkalha, Z., I. Reid, and B. Dehe. (2019). "The Role of Absorptive Capacity within Supply Chain Quality Integration." *Supply Chain Management: An International Journal,* 24 (6), pp.805–820.

Al-Odeh, M., Smallwood, J., & Badar, M. A. (2021). A framework for implementing sustainable supply chain management. International Journal of Advanced Operations Management, 13(3), pp.212-233.

Anil, A.P. and Satish, K.P. (2013). Empirical research on TQM practices of organizations–development and validation of critical factors. *International Journal of Engineering Development and Research*, *8*(3), pp. 7–13.

Antony, J., Psomas, E., Garza-Reyes, J.A. and Hines, P., 2021. Practical implications and future research agenda of lean manufacturing: a systematic literature review. Production planning & control, 32(11), pp.889-925.

Arjona Aroca, J., Giménez Maldonado, J.A., Ferrús Clari, G., Alonso i García, N., Calabria, L. and Lara, J. (2020). Enabling a green just-in-time navigation through stakeholder collaboration. *European Transport Research Review*, *12*(1), 22. https://doi.org/10.1186/s12544-020-00417-7

Arsawan, I.W.E., Koval, V., Rajiani, I., Rustiarini, N.W., Supartha, W.G. and Suryantini, N.P.S., (2020). Leveraging knowledge sharing and innovation culture into SMEs sustainable competitive advantage. *International Journal of Productivity and Performance Management,71(2), pp 405--428*.

Atkinson, P. (2010). Lean is a cultural issue. *Management Services*, *54*(2), pp. 35–41.

Azevedo, S. G., Carvalho, H., Duarte, S. and Cruz-Machado, V. (2012). Influence of green and lean upstream supply chain management practices on business sustainability. *IEEE Transactions on Engineering Management*, *59*(4), pp. 753–765.

Bader, B.H., Badar, M.A., Rodchua, S. and McLeod, A. (2020), "A study of the balancing of lean thinking and stakeholder salience in decision-making", The TQM Journal, 32(3), pp. 441-460.

Bai, C., Satir, A. and Sarkis, J., (2019). Investing in lean manufacturing practices: an environmental and operational perspective. *International Journal of Production Research*, 57(4), pp.1037-1051.

Bajaj, S., Garg, R. and Sethi, M. (2018). Total quality management: A critical literature review using Pareto analysis. *International Journal of Productivity and Performance Management*, *67*(1), pp. 128–154. https://doi.org/10.1108/IJPPM-07-2016-0146

Belhadi, A., Kamble, S.S., Zkik, K., Cherrafi, A. and Touriki, F.E., 2020. The integrated effect of Big Data Analytics, Lean Six Sigma and Green Manufacturing on the environmental performance of manufacturing companies: The case of North Africa. Journal of Cleaner Production, 252, p.119903.

Bortolotti, T., Boscari, S. and Danese, P., 2015. Successful lean implementation: Organizational culture and soft lean practices. *International Journal of Production* Economics, 160, pp.182-201.

Caldera, H. T. S., Desha, C. and Dawes, L. (2017). Exploring the role of lean thinking in sustainable business practice: A systematic literature review. *Journal of Cleaner Production*, *167*, pp.1546–1565.

Calic, G., Shevchenko, A., Ghasemaghaei, M., Bontis, N. and Tokcan, Z.O., 2020. From sustainability constraints to innovation: enhancing innovation by simultaneously attending to sustainability and commercial imperatives. *Sustainability Accounting, Management and Policy Journal*, 11(4), pp.695-715.

Central Bank of Jordan, (2017). Fifty Third Annual Report-Research Department. Avilable at https://www.cbj.gov.jo/EchoBusV3.0/SystemAssets/1f339c1c-8792-4828-9121-a23353bbe1c3.pdf. Accessed: 06/07/2021.

Cervantes, M. J. (n.d.). *The Lean Benchmark Report: Closing the Reality Gap*. Retrieved April 20, (2021), from https://www.academia.edu/20230515/The_Lean_Benchmark_Report_Closing_the_Reality_Gap

Chan, H. K., Yin, S. and Chan, F. T. S. (2010). Implementing just-in-time philosophy to reverse logistics systems: A review. *International Journal of Production Research*, *48*(21), pp.6293–6313. https://doi.org/10.1080/00207540903225213

Chen, Z. (2015). The relationships among JIT, TQM and production operations performance: An empirical study from Chinese manufacturing firms. *Business Process Management Journal*, *21*(5), pp. 1015–1039. https://doi.org/10.1108/BPMJ-09-2014-0084

Chen, Z.-X. and Tan, K. H. (2011). The perceived impact of JIT implementation on operations performance. *Journal of Advances in Management Research*,8(2), pp.213-235.

Chiarini, A., 2011. Japanese total quality control, TQM, Deming's system of profound knowledge, BPR, Lean and Six Sigma: Comparison and discussion. *International journal of lean six sigma*,2(4), pp.332-355

Creswell, J. W. (2009). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (Third Edition). Sage publications.

Creswell, J.W., 2002. Educational research: Planning, conducting, and evaluating quantitative (p. 676). Upper Saddle River, NJ: Prentice Hall.

Damert, M., Koep, L., Guenther, E. and Morris, J., 2020. Stakeholders and socially responsible supply chain management: the moderating role of internationalization. Sustainability Accounting, Management and Policy Journal,12(4), pp 667-694.

Dey, P.K. and Cheffi, W., (2013). Green supply chain performance measurement using the analytic hierarchy process: a comparative analysis of manufacturing organisations. Production Planning & Control, 24(8-9), pp.702-720.

Dey, P.K., Malesios, C., De, D., Chowdhury, S. and Abdelaziz, F.B.,(2020). The impact of lean management practices and sustainably-oriented innovation on sustainability performance of small and medium-sized enterprises: Empirical evidence from the UK. British Journal of Management, 31(1), pp.141-161.

Dieste, M., Panizzolo, R., Garza-Reyes, J. A. and Anosike, A. (2019). The relationship between lean and environmental performance: Practices and measures. *Journal of Cleaner Production*, *224*, 120–131. https://doi.org/10.1016/j.jclepro.2019.03.243

Dornyei, Z., 2007. Research Methods in Applied Linguistics Oxford University Press. New York, 748.

Dowlatshahi, S. and Taham, F. (2009). The development of a conceptual framework for Just-In-Time implementation in SMEs. *Production Planning and Control*, *20*(7), pp.611–621.

Fornell, C. and Larcker, D. F. (1981). Structural Equation Models with Unobservable Variables and Measurement Error: Algebra and Statistics. *Journal of Marketing Research*, *18*(3), 382–388. https://doi.org/10.1177/002224378101800313

Gao, S. and Low, S.P., 2014. The Toyota Way model: an alternative framework for lean construction. *Total Quality Management & Business Excellence*, 25(5-6), pp.664-682.

Garza-Reyes, J. A., Yu, M., Kumar, V. and Upadhyay, A. (2018). Total quality environmental management: Adoption status in the Chinese manufacturing sector. *The TQM Journal*,30(1), pp.2-19.

Garza-Reyes, J.A., Kumar, V., Chaikittisilp, S. and Tan, K.H., 2018. The effect of lean methods and tools on the environmental performance of manufacturing organisations. International Journal of Production Economics, 200, pp.170-180.

Goetsch, D. L. and Davis, S. B. (2014). *Quality management for organizational excellence*. pearson Upper Saddle River, NJ.

Goetsch, D. L., & Davis, S. B. (2014). Quality management for organizational excellence. Upper Saddle River, NJ: Pearson.

Goldengorin, B. and Romanuke, V. (2021). Experimental Analysis of Tardiness in Preemptive Single Machine Scheduling. *Expert Systems with Applications*,186, 114947. https://doi.org/10.1016/j.eswa.2021.114947

Golicic, S. L. and Smith, C. D. (2013). A meta-analysis of environmentally sustainable supply chain management practices and firm performance. *Journal of Supply Chain Management*, *49*(2), 78–95.

Green, K. W., Inman, R. A., Sower, V. E. and Zelbst, P. J. (2019). Impact of JIT, TQM and green supply chain practices on environmental sustainability. *Journal of Manufacturing Technology Management*, *30*(1),pp. 26–47. https://doi.org/10.1108/JMTM-01-2018-0015

Green, K. W., Zelbst, P. J., Meacham, J. and Bhadauria, V. S. (2012). Green supply chain management practices: Impact on performance. *Supply Chain Management: An International Journal*,17(3), pp.290-305.

Gupta, S.M., 2016. Lean manufacturing, green manufacturing and sustainability. *Journal of Japan Industrial Management Association*, 67(2E), pp.102-105.

Hair, J. F., Black, W. C., Babin, B. y J. and Anderson, R. E. (2019). *Multivariate data analysis* (Eighth edition). Cengage.

Hajmohammad, S., Vachon, S., Klassen, R.D. and Gavronski, I., (2013). Reprint of Lean management and supply management: their role in green practices and performance. *Journal of cleaner production*, 56, pp.86-93.

Hines, P., Taylor, D. and Walsh, A., 2020. The Lean journey: have we got it wrong?. Total quality management & business excellence, 31(3-4), pp.389-406.

Hollingworth, D. and Valentine, S. (2014). Corporate social responsibility, continuous process improvement orientation, organizational commitment and turnover intentions. *International Journal of Quality & Reliability Management*,31(6), pp.629-651.

Honarpour, A., Jusoh, A. and Md Nor, K., (2018). Total quality management, knowledge management, and innovation: an empirical study in R&D units. *Total Quality Management & Business Excellence*, 29(7-8), pp.798-816

Huo, B., Gu, M. and Wang, Z. (2019). Green or lean? A supply chain approach to sustainable performance. *Journal of Cleaner Production*, *216*, pp.152–166.

Inman, R. A., Sale, R. S., Green Jr, K. W. and Whitten, D. (2011). Agile manufacturing: Relation to total-system JIT, supply chain performance, and organizational performance. *Journal of Operations Management*, *29*(4), pp. 343–355.

Iranmanesh, M., Zailani, S., Hyun, S., Ali, M. and Kim, K. (2019). Impact of Lean Manufacturing Practices on Firms' Sustainable Performance: Lean Culture as a Moderator. *Sustainability*, *11*(4), 1112. https://doi.org/10.3390/su11041112

Isaksson, R. (2006). Total quality management for sustainable development: Process based system models. *Business Process Management Journal*, *12*(5), 632–645. https://doi.org/10.1108/14637150610691046

Jasti, N.V.K. and Kodali, R., 2015. Lean production: literature review and trends. International Journal of Production Research, 53(3), pp.867-885.

Javadian Kootanaee, A., Babu, K. N. and Talari, H. F. (2013). Just-In-Time Manufacturing System: From Introduction to Implement. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2253243

Jermsittiparsert, K., Namdej, P. and Somjai, S., 2019. Green supply chain practices and sustainable performance: moderating role of total quality management practices in electronic industry of Thailand. International Journal of Supply Chain Management, 8(3), pp.33-46.

Jum'a L, Zimon D, Ikram M. (2021). A Relationship between Supply Chain Practices, Environmental Sustainability and Financial Performance: Evidence from Manufacturing Companies in Jordan. *Sustainability, 13,* 2152. https://doi.org/10.3390/su13042152

Kalyar, M.N., Shoukat, A. and Shafique, I., 2019. Enhancing firms' environmental performance and financial performance through green supply chain management practices and institutional pressures. *Sustainability Accounting, Management and Policy Journal*, 11(2), pp.451-476

Khalfallah, M. and Lakhal, L. (2020). The impact of lean manufacturing practices on operational and financial performance: The mediating role of agile manufacturing. *International Journal of Quality & Reliability Management*, *38*(1), pp. 147–168. https://doi.org/10.1108/IJQRM-07-2019-0244

Klassen, R. D. (2000). Just-in-time manufacturing and pollution prevention generate mutual benefits in the furniture industry. *Interfaces*, *30*(3), pp. 95–106.

Klassen, R. D. and McLaughlin, C. P. (1993). TQM and environmental excellence in manufacturing. *Industrial Management & Data Systems,93(6),pp.14-22*.

Kline, R.B. (2011). Principles and Practices of Structural Equation Modelling. The Guilford Press, New York.

Kujala, J. and Ullrank, P. (2004). Total quality management as a cultural phenomenon. *Quality Management Journal*, *11*(4), pp. 43–55.

Kumar, C. and Panneerselvam, R. (2007). Literature review of JIT-KANBAN system. *International Journal of Advanced Manufacturing Technology*, *32*, 393–408. https://doi.org/10.1007/s00170-005-0340-2

Lee, V.-H., Ooi, K.-B., Tan, B.-I. and Chong, A. Y.-L. (2010). A structural analysis of the relationship between TQM practices and product innovation. *Asian Journal of Technology Innovation*, *18*(1), 73–96.

Li, D., Zhao, Y., Zhang, L., Chen, X. and Cao, C. (2018). Impact of quality management on green innovation. *Journal of Cleaner Production*, *170*, pp. 462–470.

Lu, X., Liu, H. and Ye, W., 2010, April. Analysis failure factors for small & medium software projects based on PLS method. In 2010 2nd IEEE International Conference on Information Management and Engineering pp. 676-680. IEEE.

Lucas, M. T. (2010). Understanding environmental management practices: Integrating views from strategic management and ecological economics. *Business Strategy and the Environment*, *19*(8), pp. 543–556.

Mann, D. (2015). *Creating a lean culture: Tools to sustain lean conversions* (Third edition). CRC Press, Taylor & Francis Group.

McLean, R.S., Antony, J. and Dahlgaard, J.J., 2017. Failure of Continuous Improvement initiatives in manufacturing environments: a systematic review of the evidence. Total Quality Management & Business Excellence, 28(3-4), pp.219-237.

Mohammad Mosadegh Rad, A. (2006). The impact of organizational culture on the successful implementation of total quality management. *The TQM Magazine*, *18*(6), pp.606–625. https://doi.org/10.1108/09544780610707101

Molina-Azorín, J. F., Tarí, J. J., Claver-Cortés, E. and López-Gamero, M. D. (2009). Quality management, environmental management and firm performance: A review of empirical studies and issues of integration. *International Journal of Management Reviews*, *11*(2), pp.197–222.

Muñoz-Villamizar, A., Santos, J., Garcia-Sabater, J.J., Lleo, A. and Grau, P., 2019. Green value stream mapping approach to improving productivity and environmental performance. *International Journal of Productivity and Performance Management, 68(3), pp. 608-625.*

Nader, J., El-Khalil, R., Nassar, E. and Hong, P., 2022. Pandemic planning, sustainability practices, and organizational performance: An empirical investigation of global manufacturing firms. International Journal of Production Economics,246, p.108419.

Nawanir, G., Lim, K. T., Lee, K. L., Moshood, T. D. and Ahmad, A. N. A. (2020). Less for more: The structural effects of lean manufacturing practices on sustainability of manufacturing SMEs in Malaysia. *International Journal of Supply Chain Management*, *2*(2), pp.961–975.

Nguyen, M., Phan, A. and Matsui, Y. (2018). Contribution of Quality Management Practices to Sustainability Performance of Vietnamese Firms. *Sustainability*, *10*(2), 375. https://doi.org/10.3390/su10020375

Nugroho, A., Christiananta, B., Wulani, F. and Pratama, I. (2020). Exploring the Association among Just in Time, Total Quality and Supply Chain Management Influence on Firm Performance: Evidence from Indonesia. *Int. J Sup. Chain. Mgt*, *9*(2), 920.

Pambreni, Y., Khatibi, A., Azam, S. and Tham, J. (2019). The influence of total quality management toward organization performance. *Management Science Letters*, *9*(9), pp.1397–1406.

Phan, A.C., Nguyen, H.T., Nguyen, H.A. and Matsui, Y., (2019). Effect of total quality management practices and JIT production practices on flexibility performance: Empirical evidence from international manufacturing plants. Sustainability, 11(11), p.3093. https://doi.org/10.3390/su11113093

Podsakoff, N.P., 2003. Common method biases in behavioral research: a critical review of the literature and recommended remedies. Journal of applied psychology, 885(879), pp.10-1037.

Polyviou, M., Croxton, K.L. and Knemeyer, A.M., (2019). Resilience of medium-sized firms to supply chain disruptions: the role of internal social capital. *International Journal of Operations & Production Management*, 40(1),pp 68-91.

Powell, D., Lundeby, S., Chabada, L. and Dreyer, H., 2017. Lean Six Sigma and environmental sustainability: the case of a Norwegian dairy producer. International Journal of Lean Six Sigma,8(1), pp.53-64.

Prakash, A. and Potoski, M., 2014. Global private regimes, domestic public law: ISO 14001 and pollution reduction. *Comparative Political Studies*, 47(3), pp.369-394.

Psomas, E. and Antony, J. (2019), "Research gaps in Lean manufacturing: a systematic literature review", International Journal of Quality & Reliability Management, 36(5), pp. 815-839

Rad, A. M. M. (2006). The impact of organizational culture on the successful implementation of total quality management. *The TQM Magazine*,18(6), pp.606-625.

Ringle, C. M., Wende, S. and Becker, J.-M. (2015). *SmartPLS 3* (Version 3) [Computer software]. SmartPLS GmbH. http://www.smartpls.com

Rupasinghe, H. D. and Wijethilake, C. (2021). The impact of leanness on supply chain sustainability: Examining the role of sustainability control systems. *Corporate Governance: The International Journal of Business in Society*, 21(3), pp.410-432. https://doi.org/10.1108/CG-06-2020-0217

Sakakibara, S., Flynn, B. B., Schroeder, R. G. and Morris, W. T. (1997). The Impact of Just-in-Time Manufacturing and Its Infrastructure on Manufacturing Performance. *Management Science*, *43*(9), 1246–1257. https://doi.org/10.1287/mnsc.43.9.1246

Santos Bento, G.D. and Tontini, G., 2018. Developing an instrument to measure lean manufacturing maturity and its relationship with operational performance. *Total Quality Management & Business Excellence*, 29(9-10), pp.977-995.

Sawalha, I. and Meaton, J., 2012. The Arabic culture of Jordan and its impacts on a wider Jordanian adoption of business continuity management. *Journal of business continuity & emergency planning*, 6(1), pp.84-95.

Shah, R. and Ward, P.T., 2003. Lean manufacturing: context, practice bundles, and performance. Journal of operations management, 21(2), pp.129-149.

Shokri, A. and Li, G., 2020. Green implementation of Lean Six Sigma projects in the manufacturing sector. International Journal of Lean Six Sigma,11(4), pp.771-729.

Singh, R.K., Garg, S.K. and Deshmukh, S.G., (2010). The competitiveness of SMEs in a globalized economy: Observations from China and India. *Management research review*, 33(1), pp 54-65

Soltero, C. and Waldrip, G. (2002). Using Kaizen to reduce waste and prevent pollution. *Environmental Quality Management*, *11*(3), pp.23–23.

Sreedharan V, R. and Sunder M, V., 2018. A novel approach to lean six sigma project management: a conceptual framework and empirical application. Production Planning & Control, 29(11), pp.895-907.

Tabachnick, B., & Fidell, L. (2007). Multivariate analysis of variance and covariance. Using multivariate statistics, 3, 402-407.

Tasleem, M., Khan, N. and Nisar, A. (2018). Impact of total quality management and environmental management system on sustainable performance of selected industries in Pakistan. *Journal of Environmental Science and Management*, *21*(2).

Tasleem, M., Khan, N. and Nisar, A. (2019). Impact of technology management on corporate sustainability performance: The mediating role of TQM. *International Journal of Quality & Reliability Management*, *36*(9), 1574–1599. https://doi.org/10.1108/IJQRM-01-2018-0017

Tewari, P. S., D. Skilling, P. Kumar, and Z. Wu. (2013). Competitive small and medium enterprises: a diagnostic to help design smart SME policy (English). Washington, D. C.: World Bank Group, 1–34. Accessed 30 March 2021. http://documents.worldbank.org/curated/en/534521468331785470/Competitive-small-and-medium- enterprises-a-diagnostic-to-help-design-smart-SME-policy

The World Bank, (2021). Small and Medium enterprises (SMES) finance improving SMEs' access to finance and finding innovative solutions to unlock sources of capital. Available at https://www.worldbank.org/en/topic/smefinance. Accessed 30/06/2021.

Tortorella, G.L., Fettermann, D., Fogliatto, F.S., Kumar, M. and Jurburg, D., 2020. Analysing the influence of organisational culture and leadership styles on the implementation of lean manufacturing. *Production planning & control*, 32(15),pp.1-13.

Verma, N., Sharma, V., & Badar, M. A. (2021). Entropy-based lean, energy and six sigma approach to achieve sustainability in manufacturing system. Arabian Journal for Science and Engineering, 46(8), pp. 8105-8117.

Vinodh, S., Arvind, K. R. and Somanaathan, M. (2011). Tools and techniques for enabling sustainability through lean initiatives. *Clean Technologies and Environmental Policy*, *13*(3), pp.469–479.

Walker, H., Seuring, S., Sarkis, J., Klassen, R., Fabbe-Costes, N., Roussat, C., Taylor, M. and Taylor, A. (2014). Sustainable supply chains: A framework for environmental scanning practices. *International Journal of Operations & Production Management*,34(5),pp.664-694.

Wilburn Green, K., Toms, L. C. and Clark, J. (2015). Impact of market orientation on environmental sustainability strategy. *Management Research Review*, *38*(2), pp.217–238. https://doi.org/10.1108/MRR-10-2013-0240

Williamson, D., Lynch-Wood, G. and Ramsay, J., (2006). Drivers of environmental behaviour in manufacturing SMEs and the implications for CSR. Journal of business ethics, 67(3), pp.317-330.

Womack, J. P. and Jones, D. T. (1997). Lean thinking—Banish waste and create wealth in your corporation. *Journal of the Operational Research Society*, *48*(11), pp.1148–1148.

Wong, K.K.K., 2013. Partial least squares structural equation modeling (PLS-SEM) techniques using SmartPLS. Marketing Bulletin, 24(1), pp.1-32.

Wong, W. P. and Wong, K. Y. (2014). Synergizing an ecosphere of lean for sustainable operations. *Journal of Cleaner Production*, *85*, pp.51–66.

Yaghmaei, F., 2003. Content validity and its estimation.

Yeng, S. K., Jusoh, M. S. and Ishak, N. A. (2018). The impact of total quality management (TQM) on competitive advantage: A conceptual mixed method study in the Malaysia luxury hotel industries. *Academy of Strategic Management Journal*, *17*(2), pp.1–9.

Young, I. (2009). Beyond lean towards green: Linking manufacturing excellence with environmental sustainability. *Manufacturers' Monthly*, *25*(3), pp.14–15.

Yusr, M. M., Mokhtar, S. S. M., Othman, A. R. and Sulaiman, Y. (2017). Does interaction between TQM practices and knowledge management processes enhance the innovation performance? *International Journal of Quality & Reliability Management*,34(7), pp.955-974.

Zailani, S. H., Subaramaniam, K. S., Iranmanesh, M. and Shaharudin, M. R. (2015). The impact of supply chain security practices on security operational performance among logistics service providers in an emerging economy. *International Journal of Physical Distribution & Logistics Management,*45(7), pp.652-673.

Zelbst, P. J., Green, K. W., Abshire, R. D. and Sower, V. E. (2010). Relationships among market orientation, JIT, TQM, and agility. *Industrial Management & Data Systems*,110(5),pp.637-658.

Zheng, W., Yang, B. and McLean, G. N. (2010). Linking organizational culture, structure, strategy, and organizational effectiveness: Mediating role of knowledge management. *Journal of Business Research*, *63*(7), pp.763–771.

Zhu, Q. and Sarkis, J. (2004). Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. *Journal of Operations Management*, *22*(3), pp.265–289.

Table 1 The main LMPs components

Reference	Kanban	Lot size-reduction practices	Setup time reduction practices	JIT scheduling
Buer et al.(2021)	X		X	
Ong et al.(2021)		X	X	
Shahin et al.(2020)	X			
Sancha et al.(2020)				X
Kamble et al.(2020)	X	X	X	X
Braglia et al.(2019)	X			X
Bai et al.(2019)	X	X	X	X
Marodin et al (2018)	X	X	X	X
Sundar et al.(2014)	X	X	X	X
Rahman et al.(2013)	X			
Yang et al.(2011)	X	X	X	X
Shah and Ward (2003)		X		X

Table 2 The main components of QM

Reference	Customer focus	Product design	Statistical process
AlShehail et al.(2021)	X	X	
Oji and Oke (2020)			X
Bhaskar (2020)	X	X	X
Abbas (2020)	X		X
Al-Dhaafri and Alosani (2020)	X	X	X
Sangode and Hedaoo (2019)	X		X
Phan et al.(2019)	X		
Honarpour et al.(2018)	X		X
Sahoo and Yadav (2018)	X	X	X
Psomas and Jaca (2016)	X	X	
Al-Dhaafri et al.(2016)	X	X	X

Table 3 Respondents profile

Industry	Number of respondents
Textile manufacturing	23
Food manufacturing	170
Plastic manufacturing	54
Carton manufacturing	26
Chemical manufacturing	42

Table 4. Constructs and measurement items

Constructs	Measurement items
Kanban	• Suppliers fill the kanban containers instead of purchase orders. • Your suppliers deliver the raw materials to your company using kanban containers without using the different packaging. • Your company uses a kanban pull system for production control. • Your company uses kanban squares containers to control the production.
Lot size-reduction practices	• Your company has a small lot sizes in your factory. • Your company tends to have small lot sizes in your master schedule. • Your company aggressively works to reduce lot sizes in your factory.
Setup time reduction practices	• Your employees practice setups to minimize the time required for production. • Your company aggressively works to reduce setup times in your factory. • Your company has low setup times of equipment in your factory compared with competitors.
JIT scheduling	• Your company usually meets the production schedule. • In your company, there are breakdowns or production stoppages. • The schedule in your company is designed to allow time for catching up because of production stoppages resulting from quality problems.
Customer focus	• Your company is frequently in close contact with the customers. • Your key customers usually visit your factory. • Your key customers give you feedback on the quality and delivery performance.
Product design	• There is considerable involvement in manufacturing and quality people in your company in the early stages of products design before they reach the company. • Your company designs for producibility. • Your company makes an effort when designing for the process to list the needed specifications. • Your company emphasizes in part design is on minimizing the part count. • Your company concerns about the number of parts in an end item. • Your company reviews the designs of the new products before the product is produced and sold. • In your company, the manufacturing engineers are involved to a large extent before the introduction of new products.
Statistical process control	• In your company, a huge number of the processes are under statistical control. • Your company makes extensive use of statistical techniques to minimize variance in processes. • Your company posts charts on the shop floor showing defect rates
Environmental sustainability	• Your company makes efforts to minimize the emission of hazardous waste • Your company works to minimize the consumption of energy • Your company makes efforts to minimize the consumption of direct or indirect usage of material • Your company works to minimize the consumption of dangerous materials • Your company is keen to improve its overall environmental situation • Your company works to improve compliance in alignment with environmental regulations and standards

Quality Culture	• Your company provides meaningful incentives that reward LMPs • Your company follows a policy of non-blaming, performance-oriented, process-driven organizational atmosphere • Senior management in your company directly involved with operating employees in LMPs implementation • Your company provides employees with required training on LMPs • In your company, managers encourage their employees to apply continuous improvement knowledge and skills • In your company, the senior managers lead the deployment of LMPs • In your company, quality progress targets are defined and have been effectively communicated

Table 5. Descriptive analysis of survey data (n = 315)

Latent variables	***M**	***SD**	**Skewness**	***SE**	**Kurtosis**	***SE**
Kanban	2.26	.93859	1.176	.137	.458	.274
Lot size reduction	4.21	1.0171	-1.854	.137	2.275	.274
Setup time reduction	3.93	.92308	-1.654	.137	2.899	.274
JIT scheduling	1.88	.43671	.688	.137	6.035	.274
Customer focus	3.85	.95823	-1.512	.137	2.348	.274
Product design	4.01	.87451	-2.098	.137	4.292	.274
Statistical process control	3.18	.76642	-.963	.137	.622	.274
Environmental sustainability	4.03	.82605	-2.343	.137	5.017	.274
Quality Culture	3.83	.86939	-1.686	.137	2.885	.274
*M=Mean, SD=Standard Deviation, SE=Standard Error						

Table 6. Common Method Biasness

Total Variance Explained						
Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	14.302	36.672	36.672	13.767	35.301	35.301
2	3.797	9.736	46.408			
3	3.414	8.754	55.162			
4	2.940	7.539	62.701			
5	2.479	6.357	69.059			
6	2.269	5.818	74.877			
7	1.486	3.811	78.688			
8	1.241	3.183	81.871			
9	.923	2.368	84.239			
10	.707	1.814	86.053			
11	.578	1.482	87.535			
12	.535	1.371	88.906			
13	.447	1.147	90.053			
14	.379	.972	91.024			
15	.367	.940	91.964			
16	.282	.722	92.686			
17	.276	.708	93.395			
18	.258	.663	94.057			
19	.248	.636	94.693			
20	.209	.537	95.230			
21	.193	.496	95.726			
22	.184	.471	96.197			
23	.157	.403	96.600			
24	.152	.389	96.989			
25	.142	.363	97.352			
26	.132	.338	97.691			
27	.127	.326	98.017			
28	.123	.315	98.331			
29	.119	.304	98.636			
30	.104	.266	98.901			
31	.099	.254	99.155			
32	.073	.186	99.342			
33	.064	.163	99.505			
34	.058	.149	99.653			
35	.046	.117	99.770			
36	.045	.115	99.885			
37	.037	.094	99.979			
38	.006	.015	99.994			
39	.002	.006	100.000			
Extraction Method: Principal Axis Factoring.						

Table 7. Collinearity statistics

Latent variables	Environmental sustainability	
	Tolerance	VIF
Kanban	.963	1.039
Lot size reduction	.710	1.408
Setup time reduction	.701	1.427
JIT scheduling	.978	1.023
Customer focus	.517	1.935
Product design	.723	1.382
Statistical process control	.566	1.766

Table 8. Results of stepwise regression analysis

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.169	.167		12.994	.000
	Lot size reduction	.443	.038	.545	11.504	.000
2	(Constant)	1.503	.180		8.355	.000
	Lot size reduction	.324	.039	.399	8.269	.000
	Customer focus	.302	.042	.351	7.260	.000
3	(Constant)	1.005	.191		5.260	.000
	Lot size reduction	.245	.040	.302	6.172	.000
	Customer focus	.240	.041	.278	5.846	.000
	Product design	.267	.046	.283	5.832	.000
4	(Constant)	1.289	.238		5.410	.000
	Lot size reduction	.246	.040	.302	6.218	.000
	Customer focus	.242	.041	.281	5.931	.000
	Product design	.266	.046	.282	5.843	.000
	JIT scheduling	-.155	.079	-.082	-1.976	.049
5	(Constant)	1.476	.255		5.798	.000
	Lot size reduction	.240	.039	.296	6.090	.000
	Customer focus	.284	.046	.329	6.230	.000
	Product design	.274	.046	.290	6.021	.000
	JIT scheduling	-.162	.078	-.086	-2.074	.039
	Setup time reduction	-.087	.043	-.097	-2.018	.044

a. Dependent Variable: Env. sustainability

Table 9. Analysis of measurement model

Latent variables	Items	Factor loadings	Cronbach's Alpha	Composite Reliability	AVE
Kanban	Kanban.1	0.946	0.945	0.958	0.850
	Kanban.2	0.948			
	Kanban.3	0.928			
	Kanban.4	0.863			
Lot size reduction	LSR.1	0.951	0.942	0.963	0.896
	LSR.2	0.940			
	LSR.3	0.949			
Setup time reduction	STR.1	0.948	0.947	0.966	0.903
	STR.2	0.952			
	STR.3	0.951			
JIT scheduling	JITS.1	0.828	0.901	0.924	0.802
	JITS.2	0.901			
	JITS.3	0.953			
Customer focus	CF.1	0.964	0.961	0.975	0.927
	CF.2	0.951			
	CF.3	0.974			
Product design	PDes.1	0.923	0.966	0.972	0.832
	PDes.2	0.900			
	PDes.3	0.905			
	PDes.4	0.927			
	PDes.5	0.903			
	PDes.6	0.915			
	PDes.7	0.913			
Statistical process control	SPC1	0.866	0.847	0.907	0.765
	SPC2	0.882			
	SPC3	0.876			
Quality culture	QualityCult.1	0.905	0.960	0.967	0.806
	QualityCult.2	0.911			
	QualityCult.3	0.910			
	QualityCult.4	0.897			
	QualityCult.5	0.873			
	QualityCult.6	0.902			
	QualityCult.7	0.884			
Environmental sustainability	EnvSus.1	0.884	0.945	0.956	0.786
	EnvSus.2	0.887			
	EnvSus.3	0.895			
	EnvSus.4	0.913			
	EnvSus.5	0.887			
	EnvSus.6	0.852			

Table 10. Discriminant validity test (Fornell-Larcker Criterion)

Latent variables	1	2	3	4	5	6	7	8	9
1. Customer focus	0.963								
2. Environmental sustainability	0.517	0.886							
3. JIT scheduling	0.027	-0.081	0.896						
4. Kanban	0.035	-0.030	0.173	0.922					
5. Quality culture	0.469	0.528	-0.073	0.038	0.898				
6. Lot size reduction	0.415	0.548	-0.001	-0.016	0.506	0.947			
7. Product design	0.400	0.531	-0.005	-0.016	0.523	0.456	0.912		
8. Setup time reduction	0.499	0.193	-0.009	0.106	0.155	0.173	0.249	0.950	
9. Statistical process control	0.609	0.438	-0.015	-0.030	0.331	0.389	0.389	0.441	0.875

Table 11: Model Fit indices

Fit Measure	Estimated Model
SRMR	0.069
NFI	0.928

Table 12. Analysis of structural model

Hypotheses	Path coefficients (β)	T-value	P-value	Test result
H1. Kanban -> Env. sustainability	-0.002	0.034	0.973	Rejected
H2. Lot size reduction -> Env. sustainability	0.285	3.935	0.000**	Accepted
H3. Setup time reduction -> Env. sustainability	-0.110	2.204	0.028*	Accepted
H4. JIT scheduling -> Env. sustainability	-0.087	2.101	0.036*	Accepted
H5. Customer focus -> Env. sustainability	0.290	5.510	0.000**	Accepted
H6. Product design -> Env. sustainability	0.277	4.025	0.000**	Accepted
H7. Statistical process control -> Env. sustainability	0.089	1.828	0.068	Rejected

Note: $^{**}p<0.01$, $^{*}p<0.05$, based on two-tailed test; t=1.96

Table 13. Results of moderation analysis

Hypotheses	Path coefficients (β)	T-value	P-value	Test result
H8. Quality culture* LMPs -> Environmental sustainability	0.024	0.349	0.727	Rejected
H9. Quality culture*TQM -> Environmental sustainability	-0.177	3.104	0.002**	Accepted

Note: $^{**}p<0.01$, based on two-tailed test; t=1.96

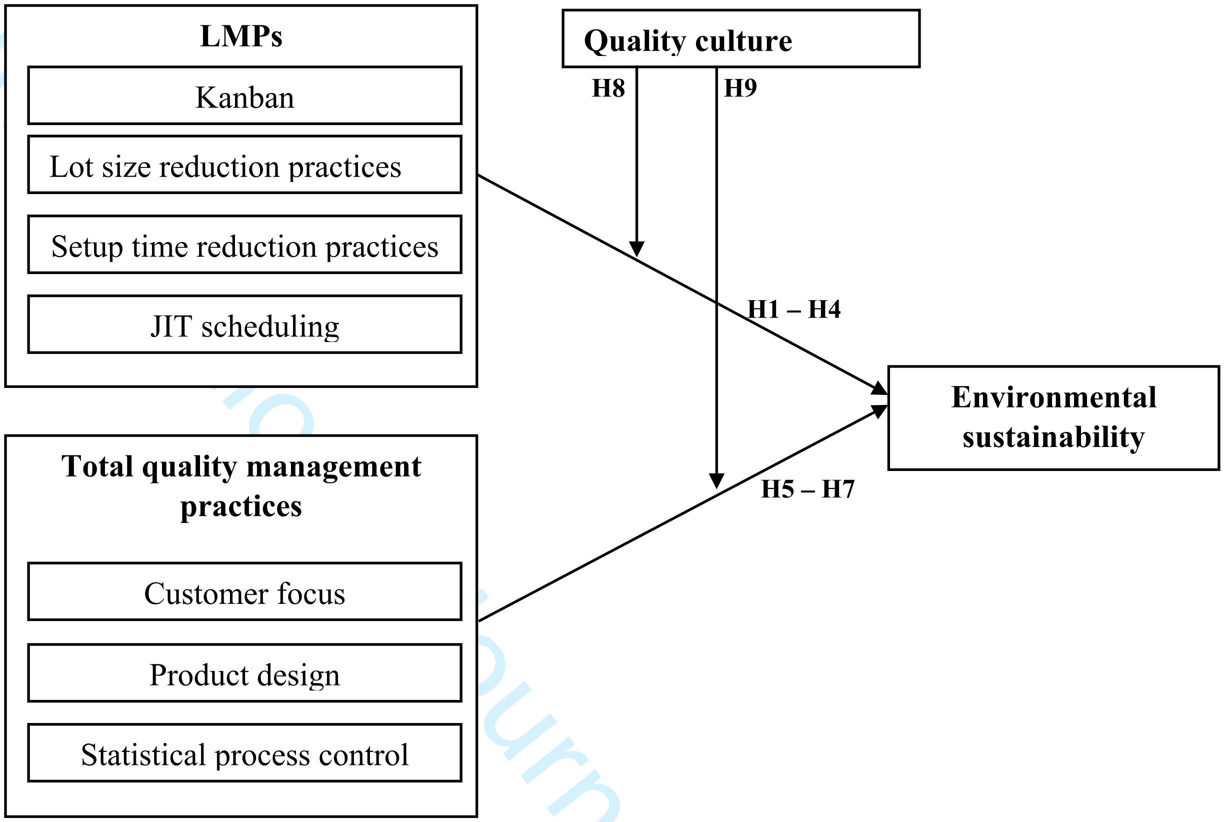

Figure 1. Theoretical framework

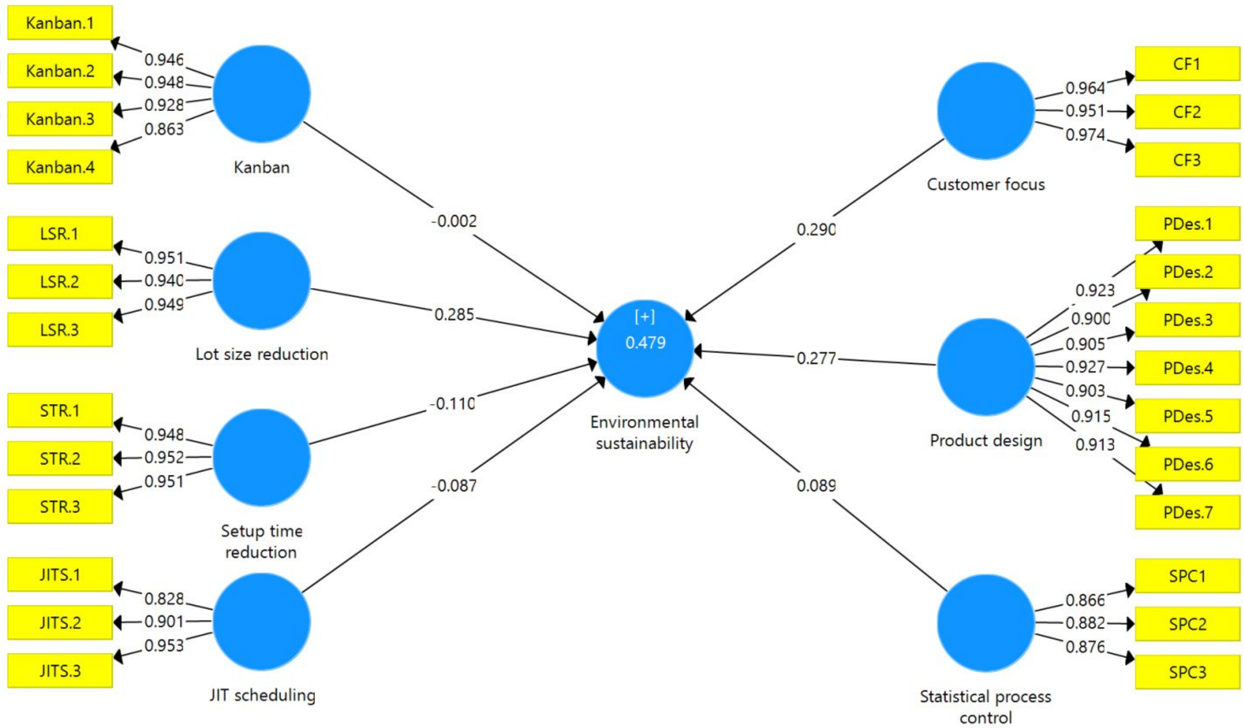

Figure 2. PLS Modelling results. LSR = Lot size reduction, STR = Setup time reduction, JITS = Just in time scheduling, CF = Customer focus, PDes = Product design, SPC = Statistical process control, EnvSus = Environmental sustainability

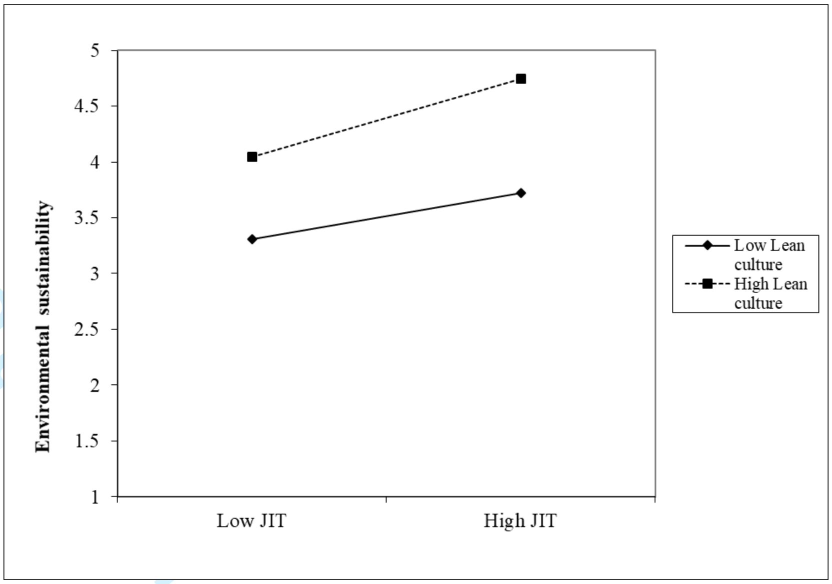

Figure 3. Interaction plot for LMPs

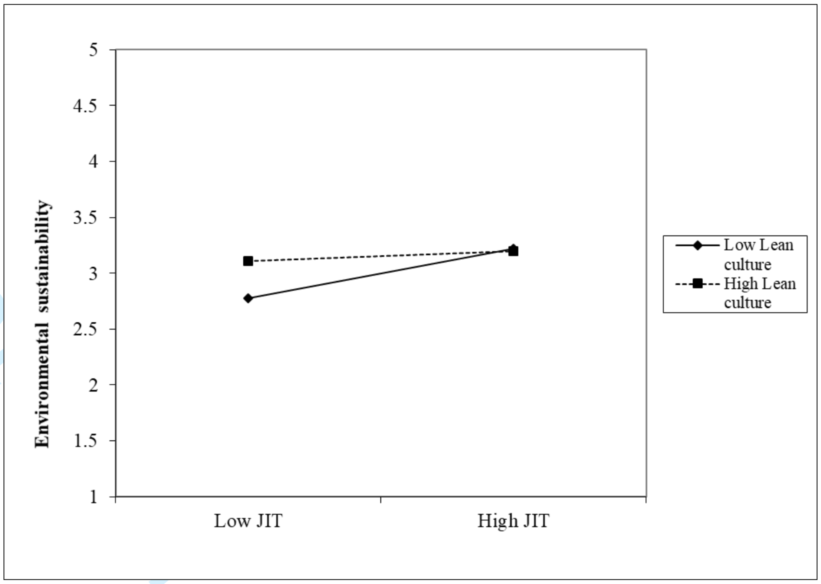

Figure 4. Interaction plot for TQM

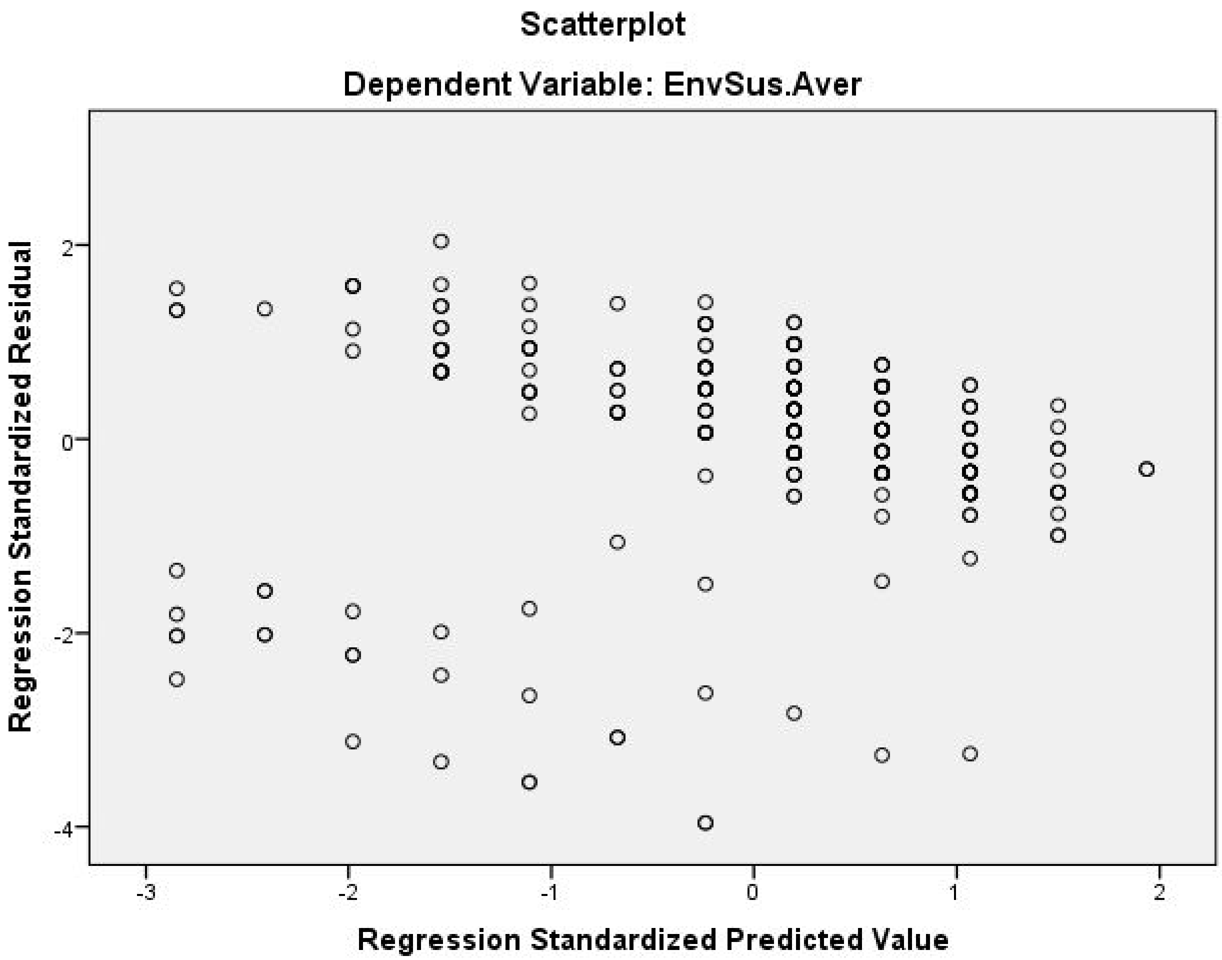

Figure 5. Heteroscedasticity scatterplot

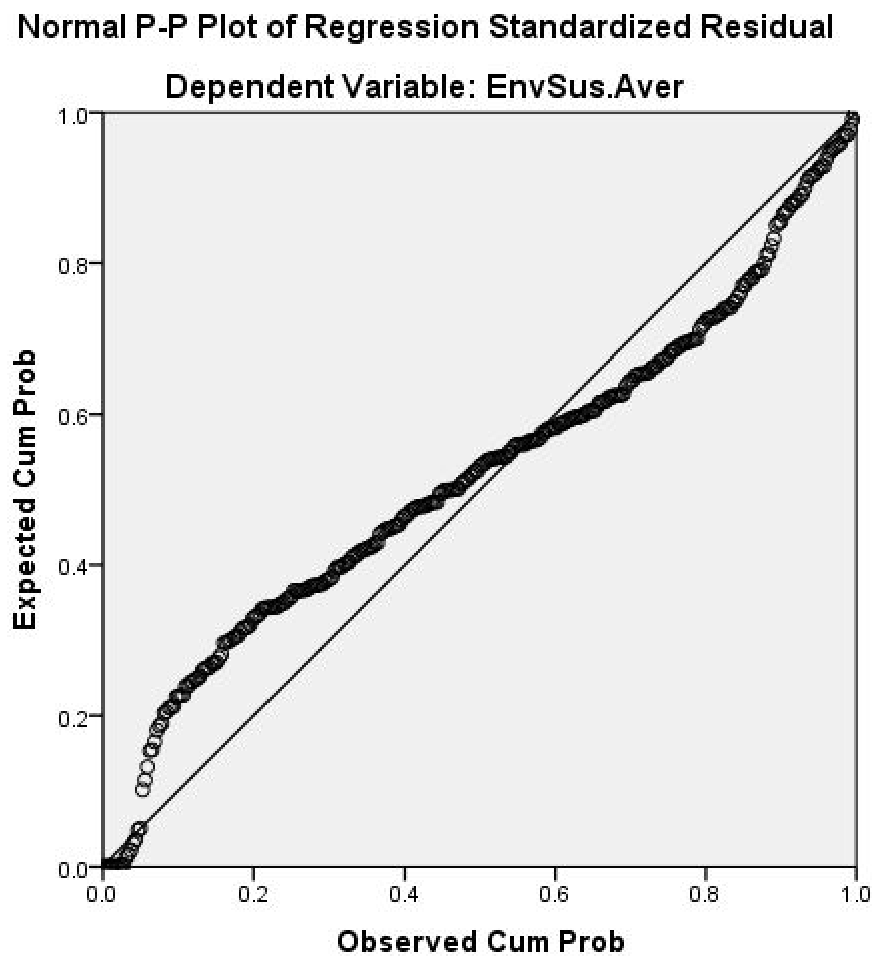

Figure 6. Residuals P-P plot