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Lean manufacturing practices for operational and business performance: A PLS-SEM modeling analysis

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Abstract

Objective: The main objective of the study is to empirically investigate the influence of lean manufacturing (LM) practices on the operational and business performance of manufacturing companies in Oman.

Methods: Empirical data on LM practices and performance were collected using a self-administered structured survey questionnaire and the sampling frame was manufacturing companies in Oman. In total 300 questionnaires were distributed among 185 companies and a total of 107 with a response rate of 35.6 percent.

Findings: The statistical analysis obtained from structural equation modeling found that lean manufacturing practices can explain operational performance, however, were unable to benefit overall business performance. Out of eight LM practices considered, small-lot production and quick setups were found to be the most adopted practices in manufacturing companies.

Novelty: Even though LM has become a fundamental aspect of industrial manufacturing processes; little is known about its impact on performance. This study adds value to the literature by examining the key LM practices-performance relationships within the manufacturing companies in Oman. These findings have significant implications for improving manufacturing organizations' operational and business performance through lean manufacturing strategies.

Keywords
Lean manufacturing, operational performance, business performance, manufacturing companies, PLS-SEM

Introduction

The operational environment of many companies has changed on an unprecedented scale due to COVID-19 pandemic. Firms need to strategize to absorb the pain of COVID-19 pandemic and operate in a highly unbalanced and volatile business atmosphere.[1,2] In today's corporate environment, the importance of the manufacturing sector in contributing to the economy and social development is becoming increasingly apparent. Companies have used several large-scale business acting techniques, like lean and supply practices, to focus on sustainable production. In the changing environment, manufacturing firms are changing

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their operations rapidly for continuous improvement together with improved quality, flexibility, and timely customer responses.[3] No doubt, LM has been widely used in the manufacturing system for increased operational and performance excellence. Despite that, still possess several limitations, such as the lack of alignment between lean and organizational objectives, lack of justified lean practices for performance measurement, and relevant indicators to evaluate such practices.[4]

In recent decades, LM and performance measurement has grown to key themes with operations management (OM). LM came into existence in the 1950s on the shop floor of a Japanese manufacturer, to identify and eliminate wastes (increased production, waiting, unnecessary transportation, improper processing, extraneous inventory, unnecessary motions, and flaws) to improve operations;[5] for business performance;[6] sustainability[7] and operational performance.[8]

According to the report submitted to the Ministry of Commerce and Industry in 2015, there was a negative effect of growth on manufacturing commodities. The service sector performed better than the productive sectors internationally. This is the reason that the manufacturing companies in Oman need more support from the government. Previous studies suggest that industrialization and globalization have diminished the performance of manu facturing companies with fierce competition. Thus, for the companies, it becomes obvious to invest internationally for future sustainable income flow. Per capita manufacturing value-added between 2007–2012 has increased from OMR 524 million to OMR 926 million that is compared to its neighboring countries, the value is still very low.[9] Thus, it is very crucial for the manufacturing companies in Oman to contribute to Oman's GDP growth with sustainable financial control and productivity as an alternative to the oil revenue.

According to,[9] Oman is far behind to progress on technological and strategic improvement as compared to its neighboring countries. Thus, this research will be a path for the manufacturing companies to improve their efficiency and productivity and work towards sustainable development and contribute to economic growth. This study will be quantitative where a survey questionnaire will be utilized to collect information from the production and supply chain managers of manufacturing companies in Oman. This study insights with tangible and intangible results with different combinations of LM factors identified that influence operational and business performance of manufacturing companies.

Various studies have been published about LM practices and their impact on business performance in general. Although many companies in the economic sectors have implemented LM practices successfully, others failed to do so. One thing that was in common of such companies was the inability to measure performance over the medium and long term.[10] This resulted in an immense interest among researchers to investigate why they are unable to measure performance derived from LM practices. In addition, it is not enough for the companies to just implement LM practices to improve performance, but they need to be aware of management responsibility on using such strategies too. Consequently, more studies need to be added to the existing literature to find the consensus on the LM-performance relationships.

The work of management scholars has identified three ways in which performance can be managed, focusing on the implementation of LM practices:[1] output control, which is related to the use of financial and non-financial performance measures;[2] behavioral control, which is enforced through operating procedures; and[3] social control, which is related to training, visualization, peer pressure, and employee empowerment.[11] Despite all these contributions by OM scholars, neither of the literature domains have provided a comprehensive review of LM in the performance measurement system. As a result, our understanding of the way performance is maintained in manufacturing companies is still unclear. This led us to perform documented evidence of LM practices towards performance. This paper contributes to the theory of LM by proposing a theoretical method for determining the extent to which LM practices are used by manufacturing companies. It contributes to theory by providing academics with a fresh approach to the scarcity of empirical investigations conducted in developing countries. It enables manufacturers in both developed and developing nations to gain a significant competitive advantage locally and globally. We built a comprehensive picture of current understanding and compared it to a holistic OM framework for critical evaluation. More, specifically, the key study objectives were:

- To investigate the influence of LM practices on the operational performance of manufacturing companies in Oman.
- To investigate the influence of LM practices on the business performance of manufacturing companies in Oman

The rest of the paper is organized in the following way to reflect these goals. The next section provides our literature review and shows the holistic LM-performance framework we used to extract and analyze the data. Research methodology is provided in section 3 where the measurement of the variables and data collection and sampling technique is explained. Section 4 provides the findings that are organized by the elements of the LM practices, operational performance and business performance analyzed using structural equation modeling. The conclusion assesses the findings seen in the results through partial least square technique. It also suggests several relevant areas for future research. We conclude with a brief conclusion that restates the research objectives and explains the significance of the findings in the study of lean manufacturing-performance relationships.

Literature review

Lean manufacturing is a systematic production method that is used to minimize waste within the production system focusing on productivity and quality.[12] Key LM practices for the manufacturing companies are the elimination of wastes, continuous improvements, respect for the human and its elements; production on time, following standard procedure, mistake proofing, and detection of defects.[13] LM has been used successfully to improve company effectiveness and efficiency. Diverse studies, however, have revealed that many businesses who try to integrate LM into their production operations fall short of their goals. LM employs a sophisticated network of socio-technical activities to increase manufacturing efficiency and provide value through waste reduction and ongoing process improvement.

Nawanir, Teong[14] investigated the relationship between LM practices and business performance in the context of 139 Indonesian manufacturing companies and found that LM practices have a positive impact on business performance. They also recommended that firms that survive in the world-based competition need to encourage LM practices implementation. Furthermore, Bai, Satir[15] focused on the relationship between LM practices and corporate environmental sustainability using a novel multi-criteria decision making (MCDM) model identifying the key issues faced by the companies about environmental sustainability and operational performance in light of the ease of LM implementation. They found that it is important to identify the locus of investments for the better selection of LM practices. They further added that it is a challenge for the organization to determine how LM practices would lead to better environmental performance. In addition, Sahoo[16] explores the relationship between social and technical aspects of LM and its impact on business performance using 148 production managers of manufacturing companies. The finding of the study revealed that social factors can enhance business performance contributing to the manufacturing strategy literature. Some of the technical indicators suggested were:[1] commit to sustainable LM implementation;[2] track mistakes on time and within the budget;[3] invest in education and training;[4] develop performance measurement system.

Gebauer, Kickuth[17] investigated the influence of LM practices on the operational performance of the pharmaceutical industry approaching 397 managers and found that overall profitability for the companies is achieved through marketing their pharmaceutical products. The findings also revealed that LM practices have a substantial contribution to operational performance. For instance, Belekoukias, Garza-Reyes[18] examined the impact of lean methods on the operational performance of 140 manufacturing companies and found that Just in Time (JIT) has a strong influence on operational performance. Similarly, Ghosh[19] investigated the LM performance in Indian manufacturing companies and found that first pass correct output, reduced manufacturing lead time, and increased productivity are the key drivers of LM practices. Sajan, Shalij[20] based on a survey of 252 manufacturing SMEs investigated the influence of LM practices on sustainable performance. The study found that environmental sustainability is correlated with economic and social sustainable performance. In another research by Kamble, Gunasekaran[21] using survey data of 115 manufacturing firms, claimed the direct effect of industry 4.0 technologies on LM practices, and organizational performance. Recently, Möldner, Garza-Reyes[22] aimed to fill the gap between research on LM practices and process innovation performance using 340 responses from selected industry experts. The findings suggested that both technical and human lean practices have a strong impact on radical process innovation performance. Next sub section will discuss on the key challenges faced by the LM practices in different countries.

Lean manufacturing challenges

When looking at the numerous obstacles across different continents (Table 1), it is clear that most organizations are still having difficulty implementing LM practices. The lack of uniform measurement and measurements across most considered countries and authors is a prevalent difficulty.[23]

Most of the authors from developed and developing nations provided a common challenge of lack of expertise and knowledge for restricting themselves from lean benefits. Additionally other authors like[33] seemed that lack of awareness, avoid responsibility and ownership,[34] apprehensive involvement found businesses challenging for the lean integration and implementation.

From the previous studies discussed within the literature, it is crucial to note that LM still needs basic practices to lay out better yield. Different attempts have been made by previous researchers to identify the best LM practices for better performance measurement.[35] Despite that, still, the overall consensus towards optimal lean practices is lacking. This review study incorporates key components of LM that do not exhaust the discussed literature throughout. As shown in Table 3, key LM practices used by previous studies have been identified, namely; flexible resources, pull system, small-lot production, quick setups, systematic production, quality at sources, total productive maintenance, and supplier relationships. Even though this study does not include all the components of LM, many were integrated into the related dimensions.

Table 1. LM challenges.

Author-year	Country	Challenges
[24]	Finland	Insufficient knowledge of production methods lacks lean benefits.
[25]	Malaysia	Issues related to knowledge are the key reason for not undertaking lean practices.
[26]	UK	The majority of the companies rejected lean due to lack of perception, lack of tangible benefits, and issues with shop floor employees.
[27]	Hungary	Lack of technical knowledge and skills causes the misapplication to LM practices.
[28]	Amsterdam	Lack of expertise and know-how on lean implementation had prevented companies to apply the lean-approach.
[29]	USA	The concern of insufficient knowledge and lack of capital funds to hire lean experts increases the awareness of lean benefits amongst companies.
[30]	Brazil	There are internal barriers like lack of employee commitment and lack of management support and interest that enable the companies to implement lean.
[31]	Australia	Companies are struggling with time, financial, and labor resources that restrict them from conducting training on LM practices.
[32]	UK	There are cultural, knowledge, and resource issues that are challenging for the companies to get lean practice benefits.

Lean manufacturing with operational and business performance

Lean manufacturing has been used to improve the competitiveness and performance of the companies in the last few decades. Many previous studies have shown that companies integrate the LM approach in their manufacturing operations with efforts to improve productivity and efficiency.

Hernandez-Matias, Ocampo[36] investigated the relationship between LM practices and operational performance in the manufacturing operations of Spanish companies using the structural equation modeling technique. They found that there is a significant relationship between management's lean culture with the employee's empowerment and involvement towards operational performance. In addition, Panwar, Jain[37] investigated the LM adoption on operational and business performance in the process industries using multivariate analysis and found that lean practices positively influence timely delivery, productivity, and demand management. Similarly, Iranmanesh, Zailani[38] used lean culture as a moderator between lean practices and sustainable performance using partial least square with 187 manufacturing firms. They found that process equipment, design, and supplier relationships is having a significant influence on sustainable performance.

As it has been discussed earlier that the manufacturing sector can play an important role as an alternative to oil companies' dependence for economic growth, it is obvious to investigate strategies to improve manufacturing companies' performance. The identification of the factors that explain the operational and business results which result from LM in the medium and long term has sparked the interest of scholars.[39] This section examines the research that focuses on this phenomenon, which is organized in the table below by the factors that are important for producing long-term results (Table 2).

Various studies have been published about LM practices and their impact on business performance in general (See Table 3). Although many companies in the economic sectors have implemented LM practices successfully, others failed to do so. One thing that was in common of such companies was the inability to measure performance over the medium and long term.[10] This resulted in an immense interest among researchers to investigate why they are unable to measure performance derived from LM practices. In addition, it is not enough for the companies to just implement lean practices to improve performance, but they need to be aware of management responsibility on using such strategies too. Consequently, more studies need to be added to the existing literature to find the consensus on the LM-performance relationships.

The concept of LM has achieved high priority in recent years[52] and it has been observed that this approach has been developed beyond the accounting and operational control.[53] To the best of our knowledge, no LM measurement instrument has been provided by research scholars that could improve operational and business performance of manufacturing companies.54 assessed the readiness of lean thinking in healthcare and suggested that patient expectations can be met with the lean setting. Similarly[55] analyzed the impact of lean on hospital performance through multiple surveys across different hospitals and concluded that lean improves performance management. Previous studies have demonstrated that lean manufacturing may have a positive impact on performance measures of manufacturing companies.[56] However,[3] suggested that instead of using lean as a single lonely activity in the operations, it must be adopted as

Table 2. Critical factors on LM practices towards performance.

Author-year	Critical factors
[4]	There is a lack of alignment between lean objective and management strategy; the lack of relevant indicators makes it difficult to measure and evaluate the leanness of a manufacturing process.
[3]	Lean must be adopted as a part of business strategy instead of only holistic operations;
[19]	Lean is about eradicating 'wastes' from the manufacturing system, but yet producing high-quality products that satisfy customers.
[40]	The manufacturing systems need to be more efficient and lean-to remain competitive. Managers rely on accounting metrics heavily to determine efficiency; however, such metrics are not enough for lean operations.
[41]	With increased environmental sustainability, organization needs to strategize efficiently and gain a competitive advantage.
[20]	Conflict of interest arises in the organization due to the focus on profits as compared to the employees and environment. Such a situation imbalances the operational and business decisions too complicated.
[11]	LM as a niche concept has been ignored for evaluating organizational performance through performance management as a holistic approach.

Table 3. Studies on lean factors.

Lean factors	References												
	42	38	16	20	43	44	45	46	47	48	49	50	51
Systematic production		X	X		x	x	x		x		X	x	
Flexible resources			X		x	x	x	X		x	X		x
Quality at source	x				x		x	X	x	x	X	x	x
Pull system			X		x			X	x	x			x
Small lot production						X	x			x	X		
Quick setups					x			X		x	X		
Supplier relationship	x	X	X		X	X	x	X	x		X		x
Total productive maintenance						X		X			X		x
Customer focus	x	X	x		X	X		X	x		x	x	x
Continuous improvement	x						x		x	x	x	x	x
Problem solving						X		X		x		x	

a complete business strategy. Some scholars[57,58] also suggested that lean might have negative impact on performance if it is not implemented for the systematic and sustainable approach in the organizations. In summary, the literature reveals two key insights. First there is mixed evidence on the best LM practices impacts the relationship among operational and business performance. Secondly, there is no direct evidence on how to use the LM practices that affects operational and business performance. Thus, the intention of our research is to examine whether LM practices can be successful by focusing solely on the operational activities in order to extract superior benefits from the LM strategies embedded deeply with business processes.

Methodology

Research framework and variable measurement

Based on the previous studies investigated and reviewed on LM, Figure 1 provides the research framework for the study.

The research review team screened out for any omissions or oversight resulting from the selection criteria. All of the papers that were chosen were retrieved from indexed publications, ensuring that the primary research was of high quality. Table 4 provides the supporting references for the LM dimensions.

Ahmad, Schroeder[70] stated that cost, quality, delivery, and flexibility are the most typical measures used to assess operational performance. Following that, Table 5 provides the supporting references for operational and business performance measured items.

According to a study by Chavez, Gimenez[73] there are positive and substantial correlations between internal lean practices and quality, delivery, flexibility, and cost. Rasi, Rakiman[74] discovered that lean has a favorable correlation with four operational performance dimensions: quality, delivery, cost, and flexibility. According to prior research, operational performance is comprised of seven key measures as cost, delivery, overtime, flexibility, quality, set up, and lead time. Organizations are transformed by locally

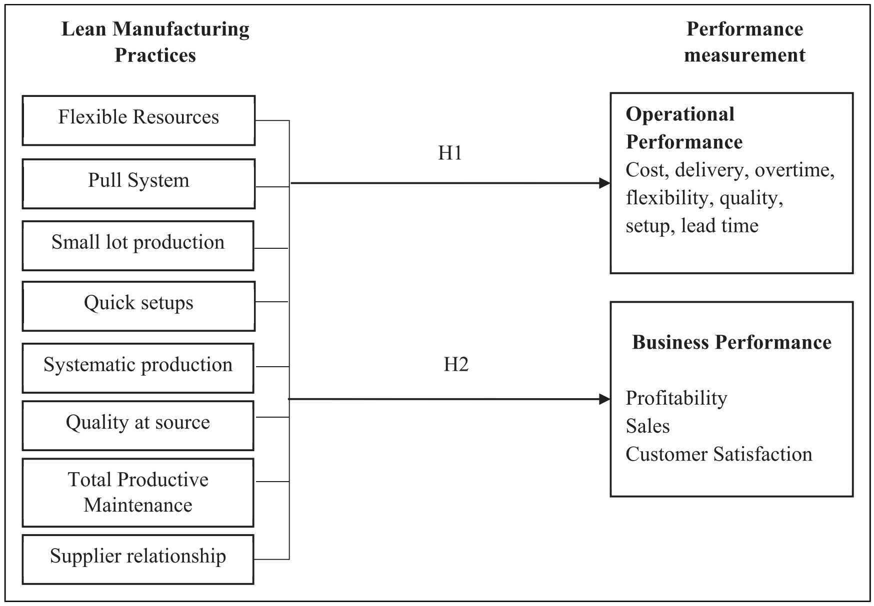

Figure 1. Research framework.

Table 4. Dimensions of LM.

Variables	Definitions	Supporting references
Flexible resources	Practice to achieve machine and employee's flexibility in the manufacturing system.	41,51,59,60
Pull system	A manufacturing system that executes the production as per the customer requirements.	19,38,59,61
Small lot production	A system of producing a small number of products at a time interval.	43
Quick setups	It is a practice of reducing the setup time in the manufacturing system.	62,63
Systematic production	It is a LM practice that reduces the production variations caused by the variability in customer demands.	64,65
Quality at source	It is the LM practice that confirms the defects of quality early and accurately and ensures each process is of no defects.	66,67
Total productive maintenance	It is the concept of maintenance combined with total quality principles to maximize efficiency and effectiveness.	59,68
Supplier relationships	It is a mutual, strategic, and collaborative business relationship between suppliers and manufacturers with a goal of waste elimination.	59,69

Table 5. Measures of performance measurement.

Dependent variables	Definitions	References
Operational performance	The ability to deliver good products or services to customers using convenient processes.	8,71
Business performance	The ability to gain profit together with targeted sales and customer satisfaction, product quality, competitive prices, and responsiveness.	6,16,72

empowered teams to project driven continuous improvements. This change in strategy led the organization to improve their efficiency and effectiveness, which positively impacts firm's operational and business performance.

Eight key LM practices as the independent variable was considered for the study that has been already implemented empirically in the operational context. The dimensions of LM were adopted keeping the manufacturing industry in view. The respondents' information was gathered using a semi-structured survey questionnaire created by adapting questions from previous studies. The variables were assessed using a five-point Likert scale ranging from "strongly disagree" to "strongly agree." To ensure the validity criteria, measurement items were adapted from previous studies (Appendix 1). The scale of the LM practices and business performance was adapted from,[59] the scale for operational performance was adapted from.[42] The questionnaire was divided into two sections: Section A was dedicated to the demographic information of the respondents. Section B contained the measurement items for the eight LM practices, operational and business performance. We used confirmatory factor analysis (CFA) to evaluate the measurement model. In order to assure the suitability of the variables, we also undertook common method bias applying procedural and statistical remedies as suggested by.[75] Despite being aware that they were responding questions about lean manufacturing and performance, respondents were not likely to anticipate our unique research model. Respondents are less likely to alter their responses in an effort to match certain presumptive expectations of the relationships if the study topic is unclear.

Sample and data collection

The study's sampling frame included all manufacturing enterprises in Oman that had implemented LM principles. Due to their direct engagement in the manufacturing operations, the data was obtained from the managers. They also possess good knowledge and experience in using LM practices in their firms. Due to LM a multidimensional approach, managers from a different department that have link to the manufacturing department were approached. The sampling list was obtained from the local business directory in Oman. Questionnaires were mailed to 300 targeted respondents in the manufacturing firms and 107 useable responses were collected resulting an effective response rate of 35.6% (107/300). We did a pretest by getting input from supply chain managers and executives who worked for companies that were implementing lean. They were tasked with rating the survey's readability, thoroughness, and clarity. As a result of their comments, we made the necessary changes to the survey instruments. Using clear, basic wording and safeguarding the respondents' privacy, we pretested the survey thoroughly to ensure that we didn't introduce any uncertainty.

Reliability and validity

The reliability and validity for the LM model can be assessed in (Table 6). Reliability was evaluated using Cronbach alpha, composite reliability (CR), and rho_A which were above 0.7 whereas, validity was evaluated using AVE result which was above 0.5, respectively[76,77] confirming the convergent validity of the constructs. Composite reliability value that do not assume equally measures like that of Cronbach Alpha.

Results

The data collected were analyzed using the partial least square (PLS) technique using SMARTPLS version 3 software.[78] The measurement model was reflective in nature where the dimensions were observed behavior of a construct. The selection of reflective or formative model is based on the nature of the covariance between the items.[79]

The discriminant validity was performed using the cross loading (Table 7), Fornell-Larcker and Hetertrait-Monotrait method (Table 7). According to Henseler, Ringle[80] the cross loading method is used to examine the items of the construct and its loading on multiple constructs.

Assessment of discriminant validity is very important for any research that involves latent variable in order to detect

Table 6. Reliability and validity for the lean model.

Variables	Cronbach's alpha	rho_A	Composite reliability	AVE
Business performance	0.756	0.998	0.846	0.650
Flexible resources	0.795	0.801	0.858	0.547
Lean manufacturing	0.812	0.836	0.847	0.225
Operational performance	0.890	0.907	0.913	0.601
Pull system	0.854	0.902	0.911	0.774
Quality at source	0.703	0.745	0.816	0.533
Quick setups	0.792	0.810	0.859	0.555
Small lot production	0.837	0.861	0.884	0.604
Supplier relationship	0.794	0.818	0.857	0.547
Systematic production	0.796	0.815	0.880	0.711
Total productive maintenance	0.717	0.746	0.820	0.533

Note: AVE = average variance extracted.

Table 7. Cross loadings of the measurement items for convergent validity.

Measurement items	BP	FR	OP	PS	QSO	QS	SLP	SR	SP	TPM
Customer satisfaction	0.773	0.06	0.078	0.013	−0.078	0.051	0.126	0.161	−0.052	0.31
Profitability	0.927	0.22	0.071	0.086	0.076	0.148	0.172	0.092	0.06	0.23
Sales	0.703	0.012	−0.006	0.008	−0.108	0.143	0.072	0.087	−0.164	0.128
FR1	0.192	0.729	0.452	0.061	0.138	0.173	0.29	0.218	0.094	0.121
FR2	0.026	0.756	0.375	0.11	0.107	0.133	0.215	0.194	0.091	0.088
FR3	0.009	0.723	0.272	0.226	0.153	0.126	0.216	0.23	0.139	−0.023
FR4	0.225	0.717	0.316	0.013	0.054	0.074	0.261	0.248	0.011	0.175
FR5	0.133	0.773	0.306	0.086	0.146	0.121	0.27	0.241	0.17	0.065
Flexibility	0.021	0.388	0.796	0.103	0.075	0.337	0.325	0.244	−0.008	0.354
Lead time	0.054	0.404	0.699	0.154	−0.013	0.08	0.23	0.229	0.022	0.264
Overtime	0.011	0.386	0.755	0.245	0.083	0.221	0.166	0.297	0.018	0.293
Cost	0.081	0.338	0.714	0.12	−0.054	0.222	0.257	0.391	0.006	0.336
Quality	0.14	0.368	0.843	0.194	0.113	0.335	0.326	0.259	−0.069	0.444
Setup	0.061	0.394	0.845	0.137	0.005	0.269	0.354	0.287	−0.035	0.353
Delivery	0.002	0.324	0.762	0.165	0.087	0.238	0.257	0.316	0.079	0.39
PS1	0.082	0.01	0.158	0.794	0.099	−0.027	0.113	0.149	0.15	0.084
PS2	0.009	0.162	0.179	0.916	0.038	0.053	0.092	0.148	0.09	0.087
PS3	0.067	0.155	0.192	0.923	0.079	0.118	0.057	0.078	0.149	0.125
QSO1	0.058	0.195	0.08	0.083	0.755	0.472	0.132	0.019	0.384	0.087
QSO2	−0.013	0.123	0.018	0.088	0.839	0.434	0.248	−0.021	0.264	−0.052
QSO3	−0.041	0.12	0.041	0.022	0.778	0.281	0.181	−0.042	0.435	0.075
QSO4	−0.019	−0.015	0.055	0.034	0.705	0.202	0.028	−0.059	0.119	0.084
QS1	0.012	0.377	0.447	0.009	0.255	0.537	0.157	0.252	0.029	0.167
QS2	−0.007	0.083	0.169	0.01	0.434	0.763	0.189	0.145	0.202	0.103
QS3	0.056	0.055	0.202	0.025	0.371	0.827	0.191	0.156	0.125	0.182
QS4	0.229	0.127	0.275	0.06	0.284	0.757	0.221	0.132	0.193	0.187
QS5	0.206	0.084	0.212	0.122	0.473	0.803	0.171	0.194	0.196	0.265
SLP1	0.09	0.12	0.152	0.036	0.163	0.158	0.748	0.11	0.126	−0.072
SLP2	0.089	0.167	0.219	0.08	0.08	0.106	0.728	0.293	0.093	0.036
SLP3	0.175	0.095	0.192	0.011	0.152	0.166	0.709	0.214	0.022	−0.029
SLP4	0.193	0.399	0.363	0.106	0.212	0.296	0.855	0.292	0.252	0.137
SLP5	0.095	0.443	0.417	0.111	0.216	0.199	0.836	0.307	0.207	0.03
SR1	−0.019	0.209	0.193	−0.047	−0.062	0.104	0.225	0.704	0.018	0.113
SR2	0.076	0.251	0.253	0.154	−0.001	0.097	0.175	0.635	−0.004	0.173
SR3	0.183	0.256	0.324	0.087	−0.009	0.272	0.207	0.824	−0.151	0.311
SR4	0.124	0.259	0.294	0.042	−0.038	0.18	0.336	0.783	−0.04	0.206
SR5	0.073	0.157	0.271	0.258	0.004	0.147	0.215	0.737	−0.057	0.293
SP1	0.023	0.159	0.014	0.135	0.367	0.088	0.118	−0.019	0.816	−0.033
SP2	−0.031	0.127	−0.012	0.19	0.411	0.208	0.176	−0.129	0.906	0.014
SP3	−0.017	0.076	−0.007	0.047	0.312	0.214	0.194	−0.026	0.804	−0.067
TPM1	0.112	0.134	0.344	0.04	0.02	0.127	0.009	0.33	−0.051	0.688
TPM2	0.271	0.183	0.434	0.106	0.008	0.25	0.13	0.318	0.04	0.783
TPM3	0.193	−0.033	0.27	0.074	0.06	0.118	−0.08	0.105	−0.064	0.754
TPM4	0.202	−0.007	0.239	0.103	0.097	0.173	−0.018	0.094	−0.057	0.691

Note: BP = Business Performance; FR = Flexible resources; OP = Operational Performance; PS = Pull System; QSO = Quality at Source; QS = Quick Setup; SLP = Small Lot Production; SR = Supplier relationship; SP = Systematic production; TPM = Total Productive Maintenance.

the multicollinearity issue.[81] In order to complement the validity of the analysis, the data were also assessed using discriminant validity through Fornell-Larcker[82] criterion and Heterotrait-Monotrait (HTMT) ratio[80] method.

The efficacy of HTMT ratio is demonstrated by means of a Monte-Carlo simulation and is highly sensitive and detect the issue of multicollinearity.[83] As per the Fornell-Larcker criterion in order to confirm the discriminant validity, the

Table 8. Discriminant validity for the constructs using Fornell-Larcker and Heterotrait-Monotrait method.

	BP	FR	OP	PS	QSO	QS	SLP	SR	SP	TPM
Fornell-Larcker criterion										
Business performance	**0.806**									
Flexible resources	0.163	**0.740**								
Operational performance	0.071	0.473	**0.775**							
Pull system	0.061	0.131	0.202	**0.880**						
Quality at source	0.000	0.165	0.064	0.082	**0.730**					
Quick setups	0.141	0.174	0.332	0.065	0.495	**0.745**				
Small lot production	0.168	0.342	0.362	0.094	0.219	0.249	**0.777**			
Supplier relationship	0.132	0.305	0.367	0.135	−0.027	0.229	0.318	**0.740**		
Systematic production	−0.013	0.140	−0.003	0.149	0.432	0.209	0.196	−0.075	**0.843**	
Total productive maintenance	0.279	0.116	0.458	0.115	0.057	0.245	0.038	0.308	−0.031	**0.730**
Heterotrait-Monotrait-ratio										
Business performance	1.00									
Flexible resources	0.23	1.00								
Operational performance	0.11	0.56	1.00							
Pull system	0.09	0.17	0.24	1.00						
Quality at source	0.20	0.23	0.13	0.12	1.00					
Quick setups	0.19	0.25	0.40	0.11	0.63	1.00				
Small lot production	0.19	0.38	0.40	0.12	0.27	0.30	1.00			
Supplier relationship	0.17	0.39	0.44	0.21	0.09	0.29	0.38	1.00		
Systematic production	0.14	0.19	0.08	0.18	0.55	0.25	0.22	0.11	1.00	
Total productive maintenance	0.35	0.20	0.54	0.16	0.17	0.30	0.16	0.38	0.11	1.00

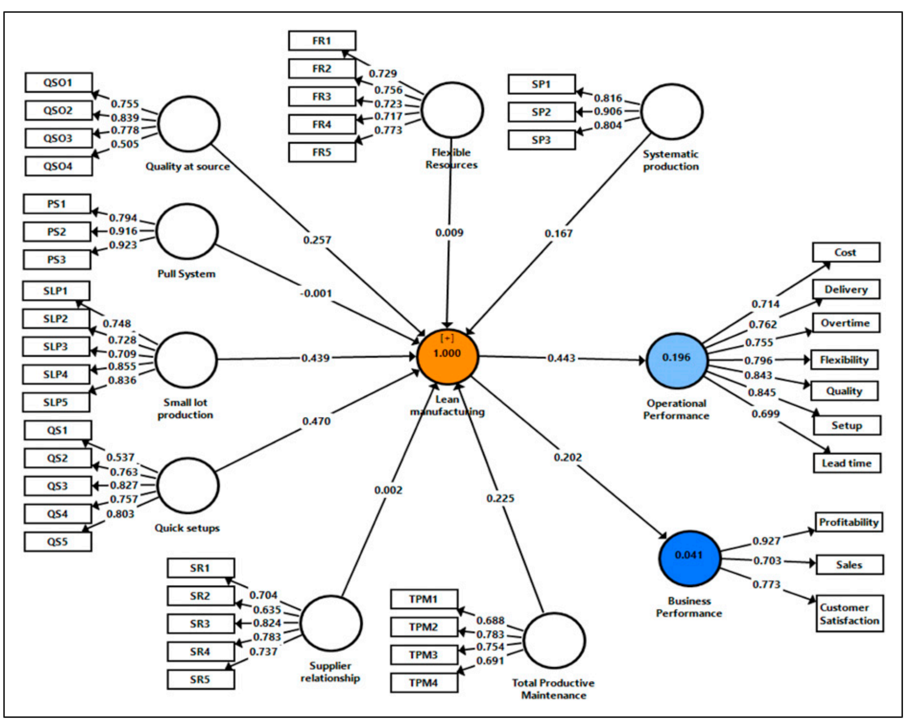

Figure 2. Evaluation of measurement and structural model using PLS algorithm.

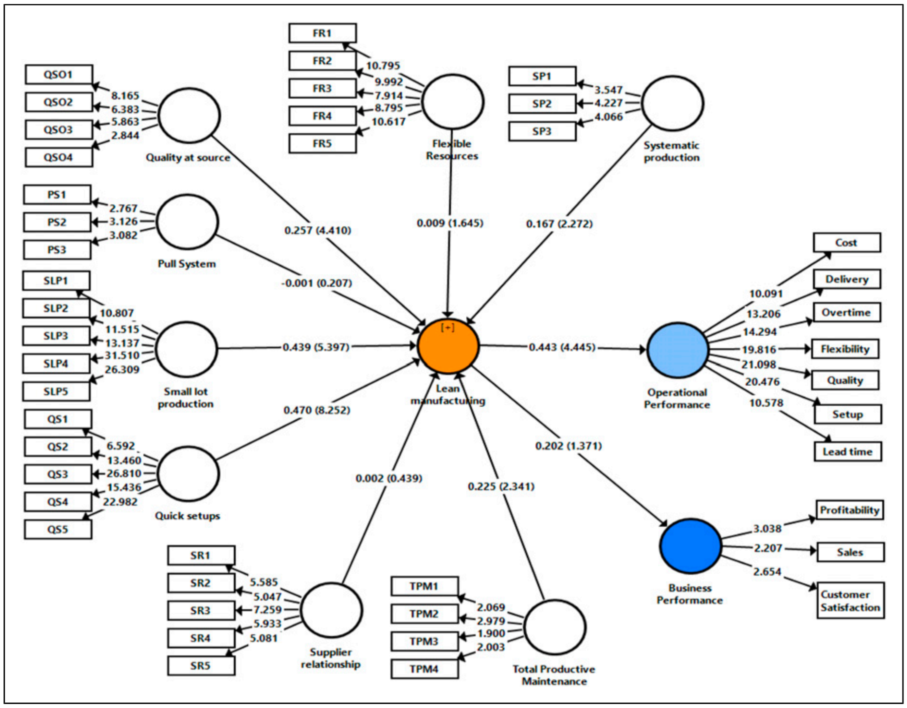

Figure 3. Evaluation of measurement and structural model using Bootstrapping algorithm.

Table 9. Structural Model results.

Standardized paths	Path coefficients	T Statistics	*p* values	Conclusion
Flexible resources - > lean manufacturing	0.009	1.516	.131	Not supported
Lean manufacturing - > business performance	0.202	1.371	.098	Not supported
Lean manufacturing - > operational performance	0.443	4.445	.000	Supported
Pull system - > lean manufacturing	−0.001	0.186	.852	Not supported
Quality at source - > lean manufacturing	0.257	4.777	.000	Supported
Quick setups - > lean manufacturing	0.470	8.842	.000	Supported
Small lot production - > lean manufacturing	0.439	5.121	.000	Supported
Supplier relationship - > lean manufacturing	0.002	0.421	.674	Not supported
Systematic production - > lean manufacturing	0.167	2.748	.007	Supported
Total productive maintenance - > lean manufacturing	0.225	2.619	.010	Supported

square root of AVE must be greater than the correlation between the constructs. The results provided in Table 8 shows that the square root highlighted are greater than the correlation between the constructs confirming the discriminant validity results. Negrão, Lopes de Sousa Jabbour[6] stated that HTMT ratio is more precise compared to Fornell Larcker criterion as it reduces bias in measurement and thus, this study also assessed discriminant validity using HTMT ratio. The HTMT value less than 0.90 is considered as good indicator to discriminant validity.[84] The correlation between the constructs shown in Table 8 confirms that none of the correlation were above 0.90 confirming the discriminant validity. (Tables 6, 7, and 8) confirmed that all the LM dimensions and performance constructs met the reliability requirements, convergent and discriminant validity criteria indicating that these indicators are adequate for explaining the constructs and they possess consistency. Overall, it is confirmed that there is a strong correlation between the endogenous and exogenous variables.

After the confirmation of reliability and validity, we assessed the structural model by observing the coefficient of determination (R2), effect size (f2), predictive relevance (Q2) and the goodness fit model. Finally, we tested the hypothesis based on the 95% confidence level using bootstrapping approach. The results from the multiple regression using PLS-SEM confirmed that there is no multicollinearity issue. The variance inflation factor (VIF) value was below 3.5 for all the variables in the model as recommended by.[85] Figure 2 presents the structural model using PLS algorithm that represents the path coefficients between the constructs.

Out of eight dimensions of LM, three dimensions (pull system, supplier relationship and flexible resources) were found to be not significant to explain LM mechanism. Similarly, the path coefficient from LM practices to business performance was not significant at 0.05 level.

Furthermore, we measured the coefficient of determination that predicts the power of the model and this coefficient represents the amount of variance in the endogenous variable explained by the exogenous variables. The R square for the coefficient path between LM and operational performance was found to be 0.196 at significant level of less than 0.01. Previous studies like Santos Bento and Tontini[42] also identified positive influence of LM on operational performance. Similarly, Jabbour, de Sousa Jabbour[86] investigating the influence of LM practices on operational performance confirmed that LM improves OP.

A bootstrap resampling approach shown in Figure 3 was used to determine the statistical significance of the coefficients of both the measurement and structural models, with the goal of generating appropriate standard errors and t-values. At a significance level (*p*-value) less than or equal to 0.01 (Hair et al., 2009),[79] the relationship between LM practices and operational performance was found to be statistically valid, whereas the relationship between LM practices and business performance was not statistically valid at a significant level less than 0.01 or 0.05. these results confirmed hypothesis 1 as accepted and hypothesis 2 to be rejected.

Table 9 show the standardized path coefficients, t value and *p* value of the relationship between the endogenous and exogenous constructs. It was found that flexible resources (t-1.516, p-0.131), pull system (t-0.186, p-0.852) and supplier relationship (t-0421, p-0.674) was unable to explain LM practices and was not supported. The standardized for LM and OP (H1) was 0.443 (t-4.445, $p < .01$) and for LM and BP (H2) was 0.202 (t-1.371, $p > .05$). The findings also demonstrate that LM improves BP by empowering OP. The result is consistent with previous studies like Rasi, Rakiman[74] conducted a study of 50 manufacturing businesses and discovered a link between lean methods and four operational performance dimensions: quality, delivery, cost, and flexibility. The studies performed in developing countries by[87,88] also concluded that LM shows encouraging signs of progress, and is an important factor for the performance. However, more effort is required to improve the implementation of LM in order to reap expected operational benefits. The current study empirically evidenced that LM practices positively influence OP confirming H1. Results also indicated that quality, flexibility, setup, total productive maintenance and delivery were the measurement items that most strongly influenced. The result for total productive mentioned is specifically coherent with the findings of[89] who found that total productive maintenance has the highest score among other LM practices and contribute to manufacturing performance. As a result, we argued that operational performance is a metric for how well an organization's internal processes work.

Conclusion and managerial implications

Despite the fact that the impact of LM practices on performance has sparked a lot of attention and debate among academics and researchers, the facts are still unclear. According to the research, LM is still evolving and may have a number of unexpected characteristics. As a result, it's reasonable to predict that the impact of lean methods on performance will vary greatly among industries and countries. This research aimed to further this line of inquiry by offering a theoretical framework for examining the direct links between LM practices and performance. The major goals of the study were to see how LM practices affect OP and BP.

The findings have a variety of consequences for industrial executives. To begin, they should resist the erroneous assumption that all LM techniques are best practices in every manufacturing and production situation. Contextual considerations, on the other hand, may limit the usage or value of LM techniques. Individual LM practices are also influenced by these factors in different ways, with some being more affected than others. As a result, managers must be able to recognize and overcome the significant social, cultural, and economic barriers that may obstruct the adoption of lean principles, lowering the chance of failure. Managers should focus on the suggested LM practices and manufacturing functions like resource allocation, operations scheduling, quality management, maintenance management and performance analysis together in order to insight overall performance of the production line and assets.

These findings have major implications for executives and operations managers involved in creating and putting into practice lean initiatives. An underlying conclusion is that lean thinking is, in fact, a holistic company strategy that relies on lean managerial accounting techniques to deliver information promptly and inspire suitable lean behaviors. To achieve the efficiency and performance improvements, management anticipate from lean efforts, they must establish effective communication and a working relationship with management. Managers should get most benefits from the lean strategies by focusing on quality, continuous improvement, meeting customer demand and satisfaction. Thus, a practical implication is that, managers should adopt effective ways for improving LM implementation in order to overcome the challenges of becoming lean in a considerably more volatile economic and political climate than that seen in industrialized countries. Managers will have a better understanding of performance measurement as a result of this research. Managers should avoid relying solely on financial measurements like financial ratios or non-financial measures like customer satisfaction, and instead blend the two. Managers should pay close attention to their customer support plans and strategies in order to promote customer satisfaction and loyalty, both of which have been shown to improve BP.

Research limitation and direction for future research

While this work adds to both theory and practice, there are some key constraints to consider. One reason is that key managers' busy schedules made it impossible to find enough time to collect the data required for accurate results. Another source of common-method bias is the responses of a single key informant. While this study focused on key respondents in relevant managerial positions, more respondents may have offered more credible results.

Despite these limitations, we feel that this study contributes to a better knowledge of LM practices, which are frequently characterized in the research in ambiguous terms. The findings are congruent with those of other authors who indicate that LM is a critical component in obtaining higher performance levels. LM practices was found to have strong influence on OP and the results also suggests that performance is likely to affect the internal structure of the organization and add value to the overall economy. Future research should therefore investigate the implementation of LM practices across the industrial sector and its impact on the economic performance. The research scope could be extended by connecting LM practices with sustainability performance. Future studies should also explore the role of LM awareness and its importance for the successful LM implementation across the manufacturing companies. Continued study is required to have a deeper understanding of Industry 4.0 and its possible impact on LM continuous improvement activities. This advancement opens up an array of possibilities for the achievement of sustainable manufacturing.

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References

1. Maware C and Adetunji O. Lean manufacturing implementation in Zimbabwean industries: impact on operational performance. *Int J Eng Bus Manag* 2019; 11: 1847979019859790.
2. Deuse J, Dombrowski U, Nöhring F, et al. Systematic combination of Lean Management with digitalization to improve production systems on the example of Jidoka 4.0. *Int J Eng Bus Manag* 2020; 12: 1847979020951351.
3. Fullerton RR, Kennedy FA and Widener SK. Lean manufacturing and firm performance: the incremental contribution of lean management accounting practices. *J Operat Manag* 2014; 32(7–8): 414–428.
4. Cortes H, Daaboul J, Le Duigou J, et al. Strategic lean management: integration of operational performance indicators for strategic lean management. *IFAC-PapersOnLine* 2016; 49(12): 65–70.
5. Bouranta N, Psomas E and Antony J. Human factors involved in lean management: a systematic literature review. *Total Quality Manag & Bus Excellence* 2021; 33: 1–33.
6. Negrão LLL, Lopes de Sousa Jabbour AB, Latan H, et al. Lean manufacturing and business performance: testing the S-curve theory. *Production Planning & Control* 2020; 31(10): 771–785.
7. Swarnakar V, Singh A and Tiwari AK. Assessment of manufacturing process through lean manufacturing and sustainability indicators: case studies in Indian perspective. *Emerging trends in mechanical Eng. Springer* 2020: 253–263.
8. Hernandez-Matias JC, Ocampo JR, Hidalgo A, et al. Lean manufacturing and operational performance: interrelationships between human-related lean practices. *J Manu Tech Manag* 2019; 31.
9. ITA. *ICT. Sustainable Development Report*. Oman: Information Technology Authority, Sultanate of Oman, 2015.
10. Martínez-Jurado PJ and Moyano-Fuentes J. Lean management, supply chain management and sustainability: a literature review. *J Cleaner Production* 2014; 85: 134–150.
11. Bellisario A and Pavlov A. Performance management practices in lean manufacturing organizations: a systematic review of research evidence. *Production Planning & Control* 2018; 29(5): 367–385.
12. Rahman NAA, Sharif SM and Esa MM. Lean manufacturing case study with Kanban system implementation. *Procedia Economics Finance* 2013; 7(1): 174–180.
13. Sundar R, Balaji A and Kumar RS. A review on lean manufacturing implementation techniques. *Procedia Eng* 2014; 97(1): 1875–1885.

14. Nawanir G, Teong LK and Othman SN. Impact of lean practices on operations performance and business performance: some evidence from Indonesian manufacturing companies. *J Manuf Tech Manag* 2013; 24(7): 1019–1050.
15. Bai C, Satir A and Sarkis J. Investing in lean manufacturing practices: an environmental and operational perspective. *Int J Produ Res* 2019; 57(4): 1037–1051.
16. Sahoo S. Lean manufacturing practices and performance: the role of social and technical factors. *International Journal of Quality & Reliability Management* 2019; 37.
17. Gebauer H, Kickuth M and Friedli T. Lean management practices in the pharmaceutical industry. *Int J Services and Operations Managt* 2009; 5(4): 463–481.
18. Belekoukias I, Garza-Reyes JA and Kumar V. The impact of lean methods and tools on the operational performance of manufacturing organisations. *Int J Production Research* 2014; 52(18): 5346–5366.
19. Ghosh M. Lean manufacturing performance in Indian manufacturing plants. *J Manuf Tech Manage* 2013; 24.
20. Sajan M, Shalij P and Ramesh A. Lean manufacturing practices in Indian manufacturing SMEs and their effect on sustainability performance. *J Manufact Tech Manage* 2017; 28.
21. Kamble S, Gunasekaran A and Dhone NC. Industry 4.0 and lean manufacturing practices for sustainable organisational performance in Indian manufacturing companies. *Int J Production Research* 2019; 58: 1–19.
22. Möldner AK, Garza-Reyes JA and Kumar V. Exploring lean manufacturing practices' influence on process innovation performance. *J Business Research* 2020; 106: 233–249.
23. Duarte S and Cruz-Machado V. Modelling lean and green: a review from business models. *Int J Lean Six Sigma* 2013; 4.
24. Rymaszewska AD. The challenges of lean manufacturing implementation in SMEs. *Benchmarking: An Int J* 2014; 21.
25. Abu F, Gholami H, Saman MZM, et al. The implementation of lean manufacturing in the furniture industry: a review and analysis on the motives, barriers, challenges, and the applications. *J Cleaner Production* 2019; 234: 660–680.
26. Melton T. The benefits of lean manufacturing: what lean thinking has to offer the process industries. *Chemical Engi Research and Design* 2005; 83(6): 662–673.
27. Losonci D, Demeter K and Jenei I. Factors influencing employee perceptions in lean transformations. *Int J Production Economics* 2011; 131(1): 30–43.
28. Lameijer BA, Veen DT, Does RJ, et al. Perceptions of lean six sigma: a multiple case study in the financial services industry. *Quality Manage J* 2016; 23(2): 29–44.
29. Abolhassani A, Layfield K and Gopalakrishnan B. Lean and US manufacturing industry: popularity of practices and implementation barriers. *Int J Product Perform Manage* 2016; 65.
30. Nunes JRR, da Silva JEAR, da Silva Moris VA, et al. Cleaner production in small companies: proposal of a management methodology. *J Clean Prod* 2019; 218: 357–366.
31. Caldera H, Desha C and Dawes L. Evaluating the enablers and barriers for successful implementation of sustainable business practice in 'lean'SMEs. *J Clean Prod* 2019; 218: 575–590.
32. Erdil NO, Aktas CB and Arani OM. Embedding sustainability in lean six sigma efforts. *J Clean Prod* 2018; 198: 520–529.
33. Cherrafi A, Elfezazi S, Chiarini A, et al. The integration of lean manufacturing, Six Sigma and sustainability: a literature review and future research directions for developing a specific model. *J Clean Prod* 2016; 139: 828–846.
34. Kurdve M, Zackrisson M, Wiktorsson M, et al. Lean and green integration into production system models–experiences from Swedish industry. *J Clean Prod* 2014; 85: 180–190.
35. Zanon LG, Ulhoa TF and Esposto KF. Performance measurement and lean maturity: congruence for improvement. *Prod Plan & Cont* 2021; 32(9): 760–774.
36. Hernandez-Matias JC, Ocampo JR, Hidalgo A, et al. Lean manufacturing and operational performance. *Jo Manuf Tech Manag* 2019; 31.
37. Panwar A, Jain R, Rathore APS, et al. The impact of lean practices on operational performance–an empirical investigation of Indian process industries. *Production Planning & Control* 2018; 29(2): 158–169.
38. Iranmanesh M, Zailani S, Hyun SS, et al. Impact of lean manufacturing practices on firms' sustainable performance: lean culture as a moderator. *Sustainability* 2019; 11(4): 1112.
39. Moyano-Fuentes J, Maqueira-Marín JM, Martínez-Jurado PJ, et al. Extending lean management along the supply chain: impact on efficiency. *J Manuf Tech Manage* 2020; 32.
40. Taj S. Lean manufacturing performance in China: assessment of 65 manufacturing plants. *J Manuf Tech Manage* 2008; 19.
41. Yang MGM, Hong P and Modi SB. Impact of lean manufacturing and environmental management on business performance: an empirical study of manufacturing firms. *Int J Production Economics* 2011; 129(2): 251–261.
42. Santos Bento Gd and Tontini G. Developing an instrument to measure lean manufacturing maturity and its relationship with operational performance. *Total Quality Management & Business Excellence* 2018; 29(9–10): 977–995.
43. Nawanir G, Lim KT, Othman SN, et al. Developing and validating lean manufacturing constructs: an SEM approach. *Benchmarking: An Int J* 2018; 25.
44. Shrafat FD and Ismail M. Structural equation modeling of lean manufacturing practices in a developing country context. *Journal of Manufacturing Technology Management* 2019; 30.
45. Achanga P, Shehab E, Roy R, et al. Critical success factors for lean implementation within SMEs. *J Manuf Tech Manage* 2006; 17.
46. Alhuraish I, Robledo C and Kobi A. A comparative exploration of lean manufacturing and six sigma in terms of their critical success factors. *J Cleaner Production* 2017; 164: 325–337.
47. Kafuku JM. Factors for effective implementation of lean manufacturing practice in selected industries in Tanzania. *Procedia Manufacturing* 2019; 33: 351–358.
48. Mamat RC, Deros BM, Ab Rahman MN, et al. Soft lean practices for successful lean production system implementation

in malaysia automotive smes: a proposed framework. *Jurnal Teknologi* 2015; 77(27).
49. Elkhairi A, Fedouaki F and El Alami S. Barriers and critical success factors for implementing lean manufacturing in SMEs. *IFAC-PapersOnLine* 2019; 52(13): 565–570.
50. Hibadullah SN, Habidin NF, Zamri FIM, et al. Critical success factors of lean manufacturing practices for the Malaysian automotive manufacturers. *Int J Quality Innova* 2014; 2(3–4): 256–271.
51. Fullerton RR and Wempe WF. Lean manufacturing, non-financial performance measures, and financial performance. *Int J Operations & Production Manage* 2009; 29.
52. Farias LMS, Santos LC, Gohr CF, et al. Criteria and practices for lean and green performance assessment: Systematic review and conceptual framework. *J Clean Prod* 2019; 218: 746–762.
53. Siegel R, Antony J, Garza-Reyes JA, et al. Integrated green lean approach and sustainability for SMEs: from literature review to a conceptual framework. *J Clean Prod* 2019; 240: 118205.
54. Sohal A, de Vass T, Singh P, et al. . Assessing readiness for lean thinking in healthcare settings: the case for Oman. *Industrial Management & Data Systems* 2021;121(11): 2338-2361.
55. Shortell SM, Blodgett JC, Rundall TG, et al. Lean management and hospital performance: adoption vs. implementation. *Joint Commi J on Quality and Patient Safety* 2021; 47(5): 296–305.
56. Dieste M, Panizzolo R and Garza-Reyes JA. A systematic literature review regarding the influence of lean manufacturing on firms' financial performance. *J Manuf Tech Manage* 2021; 32(9): 101–121.
57. Galeazzo A and Furlan A. Lean bundles and configurations: a fsQCA approach. *Int J Operations & Production Manage* 2018; 38(2): 513–533.
58. Ghobakhloo M, Azar A and Tang SH. Business value of enterprise resource planning spending and scope: a post-implementation perspective. *Kybernetes* 2018; 48.
59. Nawanir G, Lim KT and Othman SN. Lean manufacturing practices in Indonesian manufacturing firms: are there business performance effects? *Int J Lean Six Sigma* 2016; 7.
60. Hartini S and Ciptomulyono U. The relationship between lean and sustainable manufacturing on performance: literature review. *Procedia Manuf* 2015; 4: 38–45.
61. Godinho Filho M, Ganga GMD and Gunasekaran A. Lean manufacturing in Brazilian small and medium enterprises: implementation and effect on performance. *International Journal of Production Research* 2016; 54(24): 7523–7545.
62. Ong CH, Koo YY, Tan OK, et al. Does rational culture matter in the relationship between lean manufacturing practices and operational productivity? *J Manuf Tech Manage* 2021; 32.
63. Issa TN. Lean manufacturing implementation in fused plastic bags industry. In: Proceedings of the 2018 10th International Conference on Information Management and Engineering, New York, United States, 2018.
64. Nawanir G, Fernando Y and Teong LK. A second-order model of lean manufacturing implementation to leverage production line productivity with the importance-performance map analysis. *Global Business Review* 2018; 19(3_suppl): S114–S129.
65. Maware C and Adetunji O. Lean impact analysis assessment models: development of a lean measurement structural model, 2018.
66. Rundall TG, Shortell SM, Blodgett JC, et al. Adoption of lean management and hospital performance: results from a national survey. *Health Care Management Review* 2021; 46(1): E10–E19.
67. Mannon M. Lean healthcare and quality management: the experience of thedacare. *Quality Manag J* 2014; 21(1): 7–10.
68. Ahuja IS, Khamba J and Choudhary R (eds). *Improved Organizational Behavior Through Strategic Total Productive Maintenance Implementation*. Chicago, Illinois, USA: ASME International Mechanical Engineering Congress and Exposition, 2006.
69. Corsten D and Felde J. Exploring the performance effects of key-supplier collaboration: an empirical investigation into swiss buyer-supplier relationships. *Int J Physical Distri & Log Manage* 2005; 35.
70. Ahmad S, Schroeder RG and Sinha KK. The role of infrastructure practices in the effectiveness of JIT practices: implications for plant competitiveness. *J Eng Tech Manage* 2003; 20(3): 161–191.
71. Alkhaldi RZ and Abdallah AB. Lean management and operational performance in health care: Implications for business performance in private hospitals. *Int J Product Perform Manage* 2019; 69.
72. Moori RG, Pescarmona A and Kimura H. Lean manufacturing and business performance in Brazilian firms. *J Operations and Supply Chain Manage* 2013; 6(1): 91–105.
73. Chavez R, Gimenez C, Fynes B, et al. Internal lean practices and operational performance: the contingency perspective of industry clockspeed. *Int J Operations & Production Manage* 2013; 33.
74. Rasi RZR, Rakiman US and Ahmad MFB (eds). Relationship between lean production and operational performance in the manufacturing industry. *IOP conference series: Materials science and engineering*. Bali, Indonesia: IOP Publishing, 2015.
75. Podsakoff PM, MacKenzie SB, Lee J-Y, et al. Common method biases in behavioral research: a critical review of the literature and recommended remedies. *J Applied Psycho* 2003; 88(5): 879.
76. Mahmud MS, Rahman MM, Masud-Ul-Hasan M, et al. Does 'COVID-19 phobia'stimulate career anxiety?: experience from a developing country. *Heliyon* 2021; 7(3): e06346.
77. Van Nguyen S and Habók A. Designing and validating the learner autonomy perception questionnaire. *Heliyon* 2021; 7(4): e06831.
78. Ringle C, Wende S and Becker J. SmartPLS 2015. Available at: http://www.smartpls.com
79. Hair JF. Multivariate data analysis, 2009.

80. Henseler J, Ringle CM and Sarstedt M. A new criterion for assessing discriminant validity in variance-based structural equation modeling. *J Acad of Market Sci* 2015; 43(1): 115–135.
81. Panigrahi S, Azizan NAB and Al Shamsi IR. Product Innovation, Customer Satisfaction, and Brand Loyalty of Using Smartphones Among University Students: PLS–SEM Approach. *Indian J Marketing* 2021; 51(1): 8–25.
82. Fornell C and Larcker DF. *Structural equation models with unobservable variables and measurement error: algebra and statistics*. Los Angeles, CA: Sage Publications Sage CA, 1981.
83. Ab Hamid M, Sami W and Sidek M (eds) Discriminant validity assessment: use of Fornell & Larcker criterion versus HTMT criterion. *Journal of Physics: Conference Series*. IOP Publishing, 2017.
84. Benitez J, Henseler J, Castillo A, et al. How to perform and report an impactful analysis using partial least squares: Guidelines for confirmatory and explanatory IS research. *Information & Management* 2020; 57(2): 103168.
85. Field A. *An adventure in statistics: the reality enigma*. Los Angeles, CA: Sage, 2016.
86. Jabbour CJC, de Sousa Jabbour ABL, Govindan K, et al. Environmental management and operational performance in automotive companies in Brazil: the role of human resource management and lean manufacturing. *J Clean Prod* 2013; 47: 129–140.
87. Shaaban MS and Awni AH. Critical success factors for total productive manufacturing (TPM) deployment at Egyptian FMCG companies. *J Manuf Tech Manag* 2014; 25.
88. Knol WH, Slomp J, Schouteten RL, et al. Implementing lean practices in manufacturing SMEs: testing 'critical success factors' using necessary condition analysis. *Int J Product Reseach* 2018; 56(11): 3955–3973.
89. Marodin GA, Frank AG, Tortorella GL, et al. Contextual factors and lean production implementation in the Brazilian automotive supply chain. *Supply Chain Management: An Int J* 2016; 21.
90. Nawanir G, Othman SN and Lim KT. The impact of lean manufacturing practices on operations performance: a study on Indonesian manufacturing companies. *J Tech Operations Manage* 2010; 5(2): 39–51.
91. Cua KO. *A theory of integrated manufacturing practices: relating total quality management, just-in-time and total productive maintenance*. United Stated of America: University of Minnesota, 2000.
92. Abdulmalek FA, Rajgopal J and Needy KL. A classification scheme for the process industry to guide the implementation of lean. *Eng Manage J* 2006; 18(2): 15–25.
93. Thakur A. A review on Lean Manufacturing implementation techniques: a conceptual model of Lean Manufacturing dimensions. *REST J on Emerging Trends in Modelling Manuf* 2016; 2(3): 62–72.
94. Khalfallah M and Lakhal L. The impact of lean manufacturing practices on operational and financial performance: the mediating role of agile manufacturing. *Int J Quality & Reliab Manag* 2020; 38.

Appendix 1

Measurement items of the constructs

Constructs		Measurement items
Flexible resources	[43,90–92]	1. Problems solved conducting sessions in small groups. 2. Our employees have the capability to perform different tasks. 3. If one of the production workers is absent, another production worker can take over the same responsibilities. 4. Workers are cross-trained to perform a variety of tasks. 5. We use general-purpose machines that can perform a variety of basic functions.
Pull system	[13,43]	1. To authorize production, the Kanban system is used. 2. We use a production system in which items are produced only when they are requested by users. 3. Production at a specific workstation is based on the current demand at its subsequent workstation.
Small lot productions	[43,93]	1. To increase manufacturing flexibility, we emphasize small lot sizes. 2. We produce more frequently, but in smaller batches. 3. We are working hard to reduce the size of our production lots. 4. We put an emphasis on producing a small number of items in a batch. 5. We receive products from suppliers in small batches and on a regular basis.

(continued)

(continued)

Constructs		Measurement items
Quick setups	[43,93]	1. In our plant, we're working hard to reduce machine setup times. 2. To cut down on setup time, our shop floor employees do it themselves. 3. Workers in the production line set up their own machines. 4. We emphasize the importance of putting all tools in their proper storage locations. 5. Workers in the production line are taught how to set up machines.
Systematic production	[43,93]	1. Every day, we manufacture every model of product to meet the varying demands of our customers. 2. From hour to hour and day to day, we produce multiple product models based on our master schedule. 3. We place a premium on more accurate forecasting in order to reduce production variability.
Quality at source	[43,93]	1. Employees on the shop floor have the authority to halt production if there are quality issues. 2. To identify and reduce process variances, statistical techniques are used. 3. Problems with quality can easily be traced back to their source. 4. Quality issues are easily identified by production workers.
Total productive maintenance	[43,92,93]	1. Records of routine maintenance are kept 2. We stress the importance of a good maintenance system as a strategy for achieving quality and meeting deadlines. 3. At all times, we ensure that the machines are in a high state of readiness for production. 4. We dedicate time to inspecting machines on a regular basis in order to keep them running.
Supplier relationship	[43]	1. Our suppliers provide us with materials/products as needed. (On a just-in-time basis) 2. Our vendors keep a small warehouse near our plant. 3. We work hard to build long-term relationships with our vendors. 4. We place a premium on collaborating with suppliers for mutual benefit. 5. We rely on a small number of high-performance suppliers
Operational performance	[44,94]	1. Cost 2. Delivery 3. Overtime 4. Flexibility 5. Quality 6. Setup 7. Lead time
Business performance	[44,59]	1. Profitability 2. Sales 3. Customer satisfaction