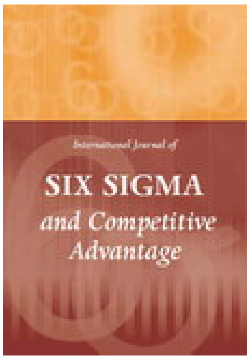

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The interplay of technical and human lean practices in enhancing operational performance: evidence from Yemeni SMEs

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The interplay of technical and human lean practices in enhancing operational performance: evidence from Yemeni SMEs

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Abstract: The current study aims to investigate the existence of a positive interplay between technical lean practices (TLPs) and human lean practices (HLPs) in enhancing operational performance with its dimensions (quality, cost, delivery, and flexibility), in the presence of industry sector and firm size as control variables. Through data collected from 318 small and medium-sized enterprises in Yemen, the proposed model was tested. The results showed that both TLPs and HLPs have synergistic effects on all dimensions of operational performance, including cost, quality, delivery, and flexibility, regardless of firm size and industry sector. This study offers theoretical and practical insights highlighting the relevance of adopting lean manufacturing practices that maximise operational performance.

Keywords: lean manufacturing practices; technical lean practices; TLPs; human lean practices; HLPs; operational performance; SMEs.

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1 Introduction

Small and medium-sized firms (SMEs) have recently been subjected to great challenges arising from the competitive nature of the economic environment, which has driven them to adopt the best practices in their industry in order to grow and sustain their operational performance. The application of new best practices in manufacturing usually has outcomes of the expectation of some benefits in the form of improved operational performance (Arumugam et al., 2020; Buer et al., 2021; Deshmukh et al., 2022; Madsen et al., 2017). Among these practices, lean manufacturing practices have emerged, which indicate a set of manufacturing techniques that concentrate on eliminating non-value-added activities (Chand et al., 2019; Chavez et al., 2015; Gebeyehu et al., 2022; Honda et al., 2018; Tripathi et al., 2022), as best practices that would benefit not only large firms (Bhasin, 2012; Nawanir et al., 2013) but even SMEs (Deshmukh and Lakhe, 2009; Godinho Filho et al., 2016). The term 'lean manufacturing' was first used in 'The machine that changed the world' by Womack and Jones (1990) to describe the manufacturing philosophy pioneered by Toyota. The philosophy has been practised at Toyota under the name of Toyota production system (TPS), which has its origins in Kichiro Toyoda's (the founder of Toyota) work way back in 1934 but has only gained global attention since 1990. In a nutshell, lean manufacturing is the endless pursuit of eliminating waste (Shingo and Dillon, 1989). Waste is anything that adds cost, but not value, to a product (Ohno, 1988).

Several empirical research have explored the impact that lean manufacturing practices have on a successful lean implementation and firm performance (Khanchanapong et al., 2014; Panwar et al., 2018). However, there is a contradiction in prior results, indicating a significant (Al-Shboul et al., 2017; Chavez et al., 2013) and non-significant (Koh et al., 2007) link between lean manufacturing practices and performance. The discrepancy in the results can be interpreted in that lean manufacturing practices were considered in previous studies from a partial rather than a comprehensive perspective (see Hadid and Mansouri, 2014; Panwar et al., 2018). According to previous studies related to this topic (Hong et al., 2014; Möldner et al., 2020), lean manufacturing practices can be categorised into two main categories: technical and human. Technical lean practices (TLPs) refer to the technical and analytical tools that seek to improve manufacturing operations (Bortolotti et al., 2015). TLPs represent practices related to operations, physical architecture, and error prevention (Hadid et al., 2016), as well as improvement tools and systems relevant to quality management and control (Lewis et al., 2006). Whilst human lean practices (HLPs) are related to behavioural issues such as leadership commitment, employee involvement, customer and supplier relationships and multi-functional integration (Abdallah et al., 2019).

Table 1 Operational performance dimensions

Supporting literature	*Efficiency*	*Quality*	*Cost*	*Flexibility*	*Delivery*	*Productivity*	*Customer satisfaction*	*Employee morale*
Samson and Terziovski (1999)		√			√	√	√	√
Ketokivi and Schroeder (2004a)	√	√				√		
Devaraj et al. (2007)		√	√	√	√			
Chavez et al. (2013)		√	√	√	√			
Khanchanapong et al. (2014)		√	√	√	√			
Al-Sa'di et al. (2017)		√	√	√	√			

Even now, a few authors have combined TLPs with HLPs (e.g., Hong et al., 2014; Möldner et al., 2020), or with social lean practices (e.g., Arumugam et al., 2020). However, these studies have focused on determining their unique effects (Arumugam et al., 2020; Hong et al., 2014). In addition, although previous studies emphasised the importance of both TLPs and HLPs as valuable resources for firms, they have not shown the potential interaction between them and whether the benefits achieved from one resource interact with the benefits achieved from the other resource. Accordingly, we claim, based on the resource-based view (RBV) and complementarity theory, that integrating distinct resource bundles can lead to synergistic impacts on OP (Khanchanapong et al., 2014). Through this work, we develop an understanding by defining TLPs and HLPs as complementary resources. Therefore, we seek to fill this gap by simultaneously exploring the unique and interplay effects of both TLPs and HLPs on operational performance, using data obtained from 318 Yemeni manufacturing SMEs. Although SMEs dominate the Yemeni manufacturing sector (Al-Hakimi and Borade, 2020; Al-Hattami, 2022; Goaill and Al-Hakimi, 2021), their contribution to the country's GDP is negligible (Al-Hakimi et al., 2021a, 2021b; Al-Hattami and Kabra, 2022; Al-Hattami et al., 2022; World Bank, 2015), where the manufacturing sector's contribution to the national GDP fell from 19% between 1990 and 1994 to 15% between 2005 and 2010, according to the World Bank's (2015) report. USAID (2020) also reported that manufacturing SMEs in Yemen contribute just 9.9% of GDP, and employ just 4% of the workforce, which is low compared to many countries. So, it is necessary to investigate their low performance.

Our study contributes to knowledge in many aspects. First, we expand the scope of recent research work by focusing on lean manufacturing practice from a comprehensive perspective. Second, we study the interplay between TLPs and HLPs in improving operational performance relying on RBV and complementarity theory as theoretical lenses. Third, we examine the relationship of lean manufacturing practices to operational performance in the context of Yemeni manufacturing SMEs, which was not addressed in the prior research. In doing so, we respond to a call by Khanchanapong et al. (2014) to conduct further research on this issue. As a result, this study adds to the body of knowledge about lean in different environments.

The remaining part of this work is structured as follows. The next section discusses the theoretical background, including the theoretical foundation and the main study constructs. While Section 3 includes hypotheses development. Section 4 contains the details of the methods used in this study. Section 5 includes the results of the data analysis and hypotheses testing. Section 6 provides a discussion of the results along with their implications. Finally, Section 7 concludes this study by conclusions and limitations.

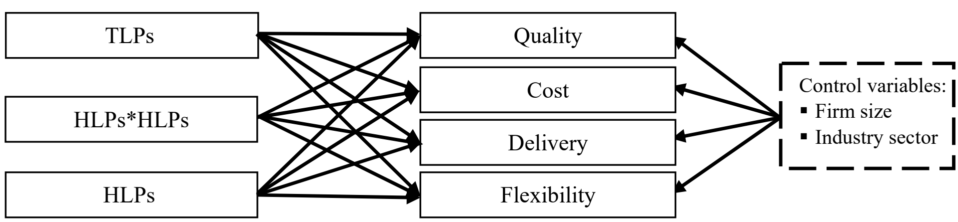
2 Theoretical background

2.1 Theoretical foundation

As a theoretical foundation, this study adopted RBV (Barney, 1991) and Complementarity theory (Mahapatra et al., 2010) to link resources (e.g., TLPs and HLPs) with operational performance (see Figure 1). It has been shown by RBV that enterprises' resource heterogeneity can explain differences in competitive and even sustainable performance (Al-Hakimi et al., 2022a; Al-Sa'di et al., 2017; Ketokivi and Schroeder, 2004a). Resources are referred to as all assets, organisational processes, knowledge, technologies, firm qualities, and other assets that enable the firm to conceptualise and implement plans that increase its efficiency and effectiveness (Barney, 1991). As such, the resources of a firm are its strengths, which are identified by their connection to the performance that is the primary result of interest (Amundson, 1998). Several studies have relied on RBV to examine how lean manufacturing practices are deployed as performance-improving regulatory resources (e.g., Khanchanapong et al., 2014; Zahra and Das, 1993). In this study, RBV directs us to investigate the unique influence of both TLPs and HLPs (as valuable and non-imitable resources) in predicting operational performance, based on the presumption that the association between each practice and performance may be unique (Ketokivi and Schroeder, 2004a). We also investigate the interactive effects of TLPs and HLPs in predicting operational performance in the light of RBV, as the combination of complementary resources increases resource complexity, making it more difficult for competitors to duplicate; this would result in improved performance.

Besides RBV, we are also guided by complementarity theory. According to complementarity theory, a firm's resources can be used or applied in ways that raise its strategic value relative to other resources (Amit and Schoemaker, 1993). Thus, TLPs and HLPs, when used together, are expected to contribute more to operational performance improvement than using each resource individually.

Figure 1 Theoretical framework



2.2 *Lean manufacturing practices*

The generic term 'lean' has emerged in the 1950s from the TPS. In the 1970s, this methodology was published to show that its characteristics were the success key of Japanese companies, particularly in the automotive sector (Dossou et al., 2022). It was then brought to light in the 1980s from the International Motor Vehicle Programme researchers of the Massachusetts Institute of Technology. The project was focussed to bridge the significant performance gap between Western and Japanese automotive industries. After the seminal work 'The Machine That Changed the World' (Womack et al., 1990) lean concept has popularised in manufacturing. Hines et al. (2004) discuss about this evolution of lean. They found that the distinction of lean thinking at the strategic level and lean production at the operational level is crucial to understand lean as a whole in order to apply the right tools and strategies to provide customer value. In early 1990s lean manufacturing concept was viewed as a counter-intuitive alternative to traditional Fordism manufacturing model (Womack et al., 1990). Lean manufacturing is generally described from two points of view, either from a philosophical perspective related to guiding principles and overarching goals (Klein et al., 2022; Shingo and Dillon, 1989; Spear and Bowen, 1999; Womack and Jones (1996), or from the practical perspective of a set of management practices, tools, or techniques that can be observed directly (Shah and Ward, 2003).

Lean manufacturing consists of a set of practices that increase the strength of processes by eliminating wastes in all forms like low level of setup times and stocks and so on (AP et al., 2020; Pozo et al., 2017; Sodhi et al., 2019). Many researchers viewed lean manufacturing from two perspectives: technical (hard) and human (soft) (Abdallah et al., 2019; Hadid et al., 2016; Möldner et al., 2020). HLPs deal with human resource management, relationships, and managerial challenges (Bortolotti et al., 2015). HLPs, in general, are concerned with behavioural concerns relating to human resources such as leadership commitment, employee involvement, customer and supplier relationships, and multi-functional integration (Abdallah et al., 2019; Hernandez-Matias et al., 2019). In contrast to the human aspects of lean, technical dimensions of lean are more tangible, as they are system-driven and easier to quantify (Gadenne and Sharma, 2009). TLPs represent the technical aspects that boost industrial operations (Bortolotti et al., 2015). They comprise practices relevant to operations, physical structure, and error forbidding (Hadid et al., 2016), as well as quality control and management improvement tools and systems (Lewis et al., 2006).

2.3 Operational performance

Operational performance has been intensively studied over decades, yet there is no commonly accepted definition because of differing perspectives and interpretations (Al-Hakimi et al., 2022b; Al-Hattami et al., 2021c). Tan et al. (2007, p.5137) deliver a general and frequently cited definition by describing it as ‘the output or result achieved due to unique operational capabilities.’ For this study, it is relied on the definition of operational performance by Dora et al. (2013, p.159), describing it as ‘the changes that occur in the operational metrics after the implementation of lean manufacturing practices in a firm.’ Compared to others, this definition reflects a view centred on the outcomes achieved due to the implementation of lean manufacturing practices by firms, supporting that the overall aim of these practices is to eliminate waste that affects process performance.

Operational performance is typically measured with a set of indicators that reflect a firm’s internal operations in terms of efficiency, productivity, product components, and process quality (Ketokivi and Schroeder, 2004a). While some studies rely on productivity, output quality, delivery performance, as well as customer satisfaction, and employee morale in measuring operational performance (e.g., Samson and Terziovski, 1999). However, quality, cost, delivery, and flexibility represent the most common measures of operational performance in many studies (e.g., Al-Sa’di et al., 2017; Chavez et al., 2013; Devaraj et al., 2007; Khanchanapong et al., 2014), which were relied upon in measuring operational performance in this study. Table 1 lists the selected operational performance dimensions, as well as the literature references for each.

3 Hypotheses development

Previous literature supports the views suggesting that TLPs bring operational advantages to the firm, such as reduced cost, enhanced delivery, and quality (Chavez et al., 2013;

Hong et al., 2014). For instance, JIT ensures that products are delivered on schedule (Shah and Ward, 2003). TQM enhances and sustains product and process quality for meeting or exceeding customer expectations (Cua et al., 2001). Belekoukias et al., (2014) indicated that JIT has a strong impact on operational performance, while TPM has less effect. Furlan et al. (2011) also found that JIT and TQM mutually boost each other in influencing operational performance. Indeed, Godinho Filho et al., (2016) claim that the Brazilian SMEs which executed lean with basic practices like TPM, 5S, and quality practices results in enhanced operational performance. Maware and Adetunji (2019) indicated that operational performance was improved by implementing the lean manufacturing. Recently, Arumugam et al. (2020) concluded that TLPs significantly and positively affect operational performance. Therefore, it is hypothesised as follows:

H1 TLPs are positively correlated with operational performance [(a) quality, (b) cost, (c) delivery, and (d) flexibility].

A number of researchers argue that HLPs such as philosophical orientation, management culture, employee sharing, cross-functional communication, and empowerment programs all contribute to the effectiveness of lean manufacturing implementation (Shah and Ward, 2003, 2007). Likewise, Möldner et al. (2020) argue that HLPs such as skill development, collaboration, teamwork, engagement, leadership commitment, and structure and organisation, can increase process innovation, resulting in the effectiveness of lean programs in increasing operational performance. The association between HLPs and operational performance has also been reported (Hong et al., 2014; Lorden et al., 2014; MacDuffie, 1995). One line of research looks at the link between HLP implementation and employee satisfaction, claiming that HLPs like employee engagement in continuous improvement programs, employee training, cross-functional teams, and Kaizen events, can boost employee commitment, resulting in lean programs performance and sustainability (Al-Swidi et al., 2022; Farris et al., 2009). Empirical research indicate that employee empowerment, cooperation, and remuneration have a significant impact on employee satisfaction, increasing productivity (Jun et al., 2006). Many researchers have identified HLPs that often used in operations management literature including TML, TEL, SDP, and CRM (Bortolotti et al., 2015; Phan et al., 2011; Sahoo, 2019), which positively affect operational performance. These HLPs are critical to lean success since they improve firm performance (Abdullah et al., 2009). On the basis of the above arguments, we assume that:

H2 HLPs are positively correlated with operational performance [(a) quality, (b) cost, (c) delivery, and (d) flexibility].

Aside from the positive influence of TLPs and supportive HLPs on performance, the projected synergy between them is expected to boost performance. Previous studies emphasise the importance of both TLPs and as worthy resources for businesses. Indeed, Milgrom and Roberts (1995) claim that resources are complimentary when their returns rise or decrease in the presence of each other. In other words, resource complementarity may be synergistic (when one resource amplifies the effect of another) or suppressive (when one resource reduces the effect of another) (Jeffers et al., 2008).

Related to that, complementarity theory assumes that a resource's value in terms of contribution to performance is determined by its 'complementary' resources. That is, the failure to implement one resource will have a negative effect on the implementation of the other, resulting in the entire implementation effort failing to produce the expected results (Colbert, 2004). As such, complementary resources are likely to be positively connected. According to RBV, it is difficult for individual resources to create a competitive advantage separate from each other (Barney, 1995). Consistent with this, we believe that TLPs and HLPs are complementary to each other, and neither can achieve maximum return without supporting the other. Thus, the development of both resources is not only 'additive' (i.e., optional), but also 'necessary'. According to Amit and Schoemaker (1993), complementary resources' synergistic value may be greater than the result from each individual resource. The reason for this is that complementary resources create a unique value for the organisation, further, the synergy originating from the complementarity of resources is considerably more difficult to detect and copy than synergy arising from identical resources (Tanriverdi and Venkatraman, 2005). Based on the above, we assume that:

H3 There is a synergistic effect of TLPs and HLPs on operational performance [(a) quality, (b) cost, (c) delivery, and (d) flexibility].

4 Methodology

4.1 Sample

To attain the objectives of the study, data was collected from 318 Yemeni manufacturing SMEs. It was decided to use the Yemeni Enterprises Directory as a sampling frame, which considers one of the most credible databases for the Yemeni Ministry of Industry and Trade (YMIT) on industrial activities in Yemen. The sample of SMEs from diverse manufacturing sectors was drawn using the simple random method from the YMIT's database, which comprises contact information for enterprises, employees count, and establishment dates. In all, Yemen has over 2,106 manufacturing SMEs. SMEs were defined in the current study using the 'number of employees' criteria offered by YMIT (2014), with firms with 4–9 employees classified as small, and firms with 10–50 employees classified as medium-sized. The sample size of 327 SMEs was determined as a minimum relative to the study population size as recommended by Krejcie and Morgan (1970). To reduce the sample size error and solve the non-response problem, the sample size was doubled to 654 (Hair et al., 2011).

Each respondent was contacted and informed in detail about the nature of the survey in order to obtain their first consent to participate. A self-administered questionnaire was used to collect the necessary data from SMEs as the unit of analysis in this study who are represented by managers/or owners because of their knowledge of the firms' different activities. One respondent per firm was considered appropriate because in the sampling frame mixed-sized firms (small to large) were found, as, in the SMEs, not many participants were available (Montabon et al., 2018). There were a total of 654 questionnaires delivered to participants by e-survey (by providing the e-link via WhatsApp) and by e-mail. After multiple phone calls and emails, 341 were filled out and returned, leaving 318 usable questionnaires with a response rate of 49% after excluding 23 invalid questionnaires. Table 2 illustrates the sample's characteristics.

Table 2 The characteristics of sample

Variable	*Categories*	*Frequency*	*Percentage*
Gender	Male	251	78.93
	Female	67	21.07
Education	Secondary and below	98	30.82
	Undergraduate	172	54.09
	Postgraduate	48	15.09
Experience	Less than 5 years	33	10.38
	5–10 years	112	35.22
	More than 10 years	173	54.40
Firm size	4–9	199	62.58
	10–50	119	37.42
Industry sector	Food and beverage	101	31.76
	Packaging	38	11.95
	Plastic	23	7.23
	Furniture	51	16.04
	Apparel	42	13.21
	Chemical and petrochemical	50	15.72
	Other	13	4.09

4.2 Measures

All questionnaire items were developed using relevant published literature. For the purpose of ensuring that all items were understandable and relevant to the targeted business environment, existing items have been modified to fit the objectives of the study through in-depth interviews with the managers of 8 different SMEs. TLPs were measured using 9 items adopted from Alkhaldi and Abdallah (2019), Bortolotti et al. (2015), and Kamble et al. (2020). While HLPs were measured by 10 items adopted from Alkhaldi and Abdallah (2019) and Kamble et al. (2020). As for operational performance, it was measured using 4 items that assess cost, quality, delivery, and flexibility, which adopted from Bortolotti et al. (2015) and Habidin et al. (2018). Table 3 shows all the items of the questionnaire.

4.3 Control variables

Firm size and industrial sector were used as control variables in this study to control for organisational and environmental factors.

5 Data analysis and results

5.1 Reliability and validity

To validate the study's measures, we conducted the reliability test to see how well the scale items consistent with one another internally. As presented in Table 3, all composite reliability (CR) values were over 0.70 (Fornell and Larcker, 1981). In addition, we conducted a confirmatory factor analysis (CFA) to determine the validity of the construct, including convergent validity and discriminant validity. All factor loading values were above 0.60 (Bagozzi and Yi, 1988), while the average variance extracted (AVE) was above the cut-off point of 0.50 that is commonly accepted (Hair et al., 2011). In general, all constructs are having acceptable convergent validity.

Table 3 CFA results

Constructs	*Item code*	*Factor loading*	*CR*	*AVE*	*Mean*	*SD*
Technical lean practices	-	-	0.91	0.54	3.361	0.7389
	TLP1	0.733				
	TLP2	0.766				
	TLP3	0.729				
	TLP4	0.769				
	TLP5	0.772				
	TLP6	0.751				
	TLP7	0.719				
	TLP8	0.702				
	TLP9	0.656				
Human lean practices	-	-	0.92	0.53	3.798	0.7187
	HLP1	0.626				
	HLP2	0.669				
	HLP3	0.745				
	HLP4	0.754				
	HLP5	0.660				
	HLP6	0.757				
	HLP7	0.796				
	HLP8	0.672				
	HLP9	0.778				
	HLP10	0.777				
Quality	OP1	0.864	0.75	0.75	3.557	1.08
Cost	OP2	0.679	0.46	0.46	3.726	1.03
Delivery	OP3	0.830	0.69	0.69	3.733	1.04
Flexibility	OP4	0.761	0.58	0.58	3.387	1.09

Notes: CR = composite reliability, AVE = average variance extracted, SD = standard deviation

The results in Table 4 show the descriptive statistics of the study variables. Furthermore, the discriminant validity of latent factors is high, as shown by the root-square-values of AVE exceeding the correspondent correlations of all factors (Fornell and Larcker, 1981).

Table 4 Discriminant validity results

Constructs	*TLPs*	*HLPs*	*Quality*	*Cost*	*Delivery*	*Flexibility*
TLPs	*0.73*					
HLPs	0.52***	*0.73*				
Quality	0.39***	0.45***	*0.87*			
Cost	0.32***	0.36***	0.55***	*0.68*		
Delivery	0.33***	0.38***	0.51***	0.68***	*0.83*	
Flexibility	0.29***	0.36***	0.46***	0.56***	0.53***	*0.76*

5.2 Hypotheses testing

In order to test the hypotheses, we performed a multiple regression analysis using Hayes' Process macro with SPSS, in which direct and synergistic effects were explored (Hayes, 2018). Before analysis, we performed a variance inflation factor (VIF) test for all constructs constituting the interaction conditions to alleviate the multicollinearity threat (Aiken and West, 1991). The highest value for VIF in the current study was 1.369, which is significantly below the cut-off point of 10 (Hair et al., 2011).

Table 5 summarises the findings of the hypotheses. The findings indicate that paths (TLPs→cost) ($\beta = 0.17$, $p < 0.10$), (TLPs→delivery) ($\beta = 0.16$, $p < 0.10$), (HLPs→quality) ($\beta = 0.68$, $p < 0.01$), (HLPs→cost) ($\beta = 0.32$, $p < 0.01$), (HLPs→delivery) ($\beta = 0.37$, $p < 0.01$), and (HLPs→flexibility) ($\beta = 0.37$, $p < 0.01$) were positive and significant. Therefore, hypotheses H1b/c and H2a/b/c/d are supported. While the paths (TLPs→quality) ($\beta = 0.13$, $p > 0.10$) and (TLPs→flexibility) ($\beta = 0.12$, $p > 0.10$), were insignificant. Therefore, hypotheses H1a/d are not supported.

Table 5 Multiple regression analysis results

	Dependent variable			
	Quality	*Cost*	*Delivery*	*Flexibility*
Control variables				
Firm size	0.04	–0.005	–0.06	–0.15
Industry sector	–0.03	–0.017	0.003	–0.02
Direct effects				
TLPs	0.13	0.17*	0.16*	0.12
HLPs	0.68***	0.32***	0.37***	0.37***
Interactive effects				
TLPs×HLPs	0.41***	0.22**	0.26***	0.19**
F	21.48***	6.53***	7.95***	6.34***
R^2	0.26	0.09	0.11	0.09

Note: Standardised coefficients are reported: ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

Along with the linear aspects of our proposed model, we investigated the synergistic effects of TLPs and HLPs on all dimensions of operational performance. The results revealed that there is a synergistic effect of TLPs and HLPs on quality performance ($\beta = 0.41$, $p < 0.01$), cost ($\beta = 0.22$, $p < 0.05$), delivery ($\beta = 0.26$, $p < 0.01$), and flexibility ($\beta = 0.19$, $p < 0.05$). Therefore, hypotheses H3a/b/c/d are supported.

Furthermore, insignificant results for industry and firm size controls suggest that the interactive effect of TLPs and HLPs on operational performance dimensions of SMEs is not related to size and industry. Thence, although firm size and industry clearly may have important implications for firm behaviour and structure, they are not likely to have an overt impact on how SMEs use lean practices to improve their operational performance.

6 Discussion

This study demonstrates the importance of both TLPs and HLPs in predicting operational performance of manufacturing SMEs. The findings of the study contribute to the operations management literature through an empirical approach that yields theoretical and empirical implications and opens potential research areas for the future.

As the study results showed, both TLPs and HLPs are important in improving the operational performance of SMEs. Our results show that both TLPs and HLPs are associated with the four dimensions of operational performance (with the exception of the relationship of TLPs with the dimensions of quality and flexibility), indicating that TLPs and HLPs are useful resources for obtaining operational advantage. These results back up the findings of prior research (e.g., Arumugam et al., 2020; Godinho Filho et al., 2016). Our findings also indicate a positive association between HLPs and operational performance, which is consistent with past research (e.g., Möldner et al., 2020; Sahoo, 2019). Importantly, our results show that TLPs and HLPs have a synergistic connection in predicting the four dimensions of operational performance. This study thus expands the results of Khanchanapong et al. (2014) by showing the influence of interaction between TLPs and HLPs on the four dimensions of operational performance.

6.1 Theoretical Implications

Theoretically, this study adds to the operations management literature that aims to uncover the enablers of high operational performance (Hackman and Wageman, 1995; Ketokivi and Schroeder, 2004b). Depending on RBV as a theoretical lens, the results indicate that TLPs and HLPs have predictive power for operational performance. Importantly, the positive interaction between TLPs and HLPs demonstrates interactive relations that occur when one resource magnifies the influence of another resource, hence multiplying the overall influence of both (Black and Boal, 1994; Khanchanapong et al., 2014). Thus, our results broaden prior studies related to lean manufacturing practices (Abdallah et al., 2019; Arumugam et al., 2020).

According to RBV, there are two explanations for this interaction. First, the interaction shows that using TLPs and HLPs as resources gives a competitive edge and above-average returns. Combining two complementary resources increase resource variety, making imitation more difficult (Peteraf, 1993). Moreover, because each component of lean practices has inherent competitive value, their combination provides synergistic results that outperform their separate effects (Jeffers et al., 2008).

Second, the positive interactions indicate that the value of TLPs as resources may be contingent on the amount to which HLPs have been adopted within the organisation, and vice versa. Regarding this, RBV back up the idea that individual resources may be limited in their potential to build competitive edge, but they feed off one another to create sustained competitive advantage (Barney, 1995). According to this concept, the results of our study suggest that TLPs may require the assistance of HLPs, in the sense that when TLPs are used in conjunction with a higher degree of adoption of HLPs, the performance benefit from TLPs is increased. The findings also back up the complementarity theory regarding the interaction that exists between TLPs and HLPs. As Amit and Schoemaker (1993) point out, the resources of a firm may demonstrate complementarity in deployment or implementation in ways that raise their strategic value compared to one another. Our findings reveal a positive interaction between TLPs and HLPs in improving operational performance, indicating that investing in a number of complementary resources at the same time will result in higher performance than relying on a single type of resource alone (Milgrom and Roberts, 1995). According to complementarity theory, the total value of a firm's resources may be greater than the value of each resource when each resource is used individually.

6.2 Empirical Implications

Our findings clearly reveal the importance of TLPs and HLPs as valuable resources to improve operational performance. The findings also show that TLPs have a stronger effect on operational performance than HLPs. However, TLPs need HLPs to maximise their effect on operational performance. Most studies have emphasised that a lack of HLPs leads to failure and delay in lean transformation (Hong et al., 2014). HLPs would be helpful for SMEs to enhance the performance of their employees. The orientation towards learning lean practices and the belief that a lean system is essential to the growth of SMEs and improved operational performance (Arumugam et al., 2020). This could be a challenge for SMEs, as our analysis reveals that manufacturing SMEs in Yemen adopt TLPs less than HLPs. This may be attributed to the fact that adopting TLPs requires big investments, which several SMEs cannot afford. Thus, our findings have managerial implications for SMEs, as they should create policies to encourage Yemeni manufacturing industries to invest in TLPs.

Additionally, our findings demonstrate that while TLPs-HLPs synergy can help maximise their complementary nature, Yemeni SMEs seem to 'dichotomise' the two resources, implying that they are 'dichotomising' them and treating them independently. Therefore, the findings of this study might be helpful to support the owners and top management of SMEs in the preparation and accomplishment of an effective lean transformation.

7 Conclusions, limitations and future research

Guided by RBV and Complementarity theory, this study developed a theoretical framework to explore the interplay between TLPs and HLPs in improving operational performance. Based on the data collected from manufacturing SMEs in Yemen, the results of the study confirmed the interactive effect of TLPs and HLPs on the four dimensions of operational performance (quality, cost, delivery, and flexibility). The findings imply that performance requires specific resource configuration, providing a more nuanced picture of TLPs, HLPs, and operational performance. In addition, the performance impact of TLPs is correlated to their interactions with HLPs. As a result, failure to know these boosting interactions may result in an unnecessarily high level of emphasis being placed on particular types of engagement in these practices.

Even though the contributions of this study, we identify the following limitations, which in turn require further research in the future. First, because we employ the cross-sectional survey method, which precludes causal inference, as there are temporal effects among TLPs, HLPs, and operational performance that are not accommodated in this empirical framework. Therefore, future studies should aim to generate longitudinal data in order to grab conditional effects. Second, this study only examined the synergistic effects between TLPs and HLPs in relation to performance, future studies could include other performance-related variables that were not included in the current study. Third, this study offers unique perceptions of the links among TLPs, HLPs, and manufacturing performance in Yemeni SMEs. Our results may apply to similar environments (such as those in Asia), however, future studies can focus on specific firms' sizes, or sectors, generating a greater understanding of the links among TLPs, HLPs, and operational performance in similar situations or environments.

References

Abdallah, A.B., Dahiyat, S.E. and Matsui, Y. (2019) 'Lean management and innovation performance: Evidence from international manufacturing companies', *Management Research Review*, Vol. 42, No. 2, pp.239–262, https://doi.org/10.1108/MRR-10-2017-0363.

Abdullah, M.M.B., Uli, J. and Tari, J.J. (2009) 'The relationship of performance with soft factors and quality improvement', *Total Quality Management and Business Excellence*, Vol. 20, No. 7, pp.735–748, https://doi.org/10.1080/14783360903037051.

Aiken, L.S. and West, S.G. (1991) *Multiple Regression: Testing and Interpreting Interactions*, Sage. UK.

Al-Hakimi, M.A. and Borade, D.B. (2020) 'The impact of entrepreneurial orientation on the supply chain resilience', *Cogent Business and Management*, Vol. 7, No. 1, pp.1–18, https://doi.org/10.1080/23311975.2020.1847990.

Al-Hakimi, M.A., Borade, D.B. and Saleh, M.H. (2021a) 'The mediating role of innovation between entrepreneurial orientation and supply chain resilience', *Asia-Pacific Journal of Business Administration*, pp.1–25, https://doi.org/10.1108/APJBA-10-2020-0376.

Al-Hakimi, M.A., Saleh, M.H. and Borade, D.B. (2021b) 'Entrepreneurial orientation and supply chain resilience of manufacturing SMEs in Yemen: the mediating effects of absorptive capacity and innovation', *Heliyon*, Vol. 7, No. 10, pp.1–12, https://doi.org/10.1016/j.heliyon.2021.e08145.

Al-Hakimi, M.A., Borade, D.B., Saleh, M.H. and Nasr, M.A. (2022a) 'The moderating role of supplier relationship on the effect of postponement on supply chain resilience under different levels of environmental uncertainty', *Production and Manufacturing Research,* Vol. 10, No. 1, pp.383–409, https://doi.org/10.1080/21693277.2022.2089264.

Al-Hakimi, M.A., Saleh, M.H., Borade, D.B., Hasan, M.B. and Sharma, D. (2022b) 'Competitor orientation and SME performance in competitive environments: the moderating effect of marketing ethics', *Journal of Entrepreneurship in Emerging Economies*, pp.1–24, https://doi.org/10.1108/JEEE-12-2021-0486.

Al-Hattami, H.M., Hashed, A.A. and Kabra, J.D. (2021c) 'Effect of AIS success on performance measures of SMEs: evidence from Yemen', *International Journal of Business Information Systems*, Vol. 36, No. 1, pp.144–164, https://doi.org/10.1504/IJBIS.2021.112399.

Al-Hattami, H.M., Abdullah, A.A.A.H., Kabra, J.D., Alsoufi, M.A.Z., Gaber, M.M.A. and Shuraim, A.M.A. (2022) 'Effect of AIS on planning process effectiveness: a case of SMEs in a less developed nation', *The Bottom Line*, pp.1–19, https://doi.org/10.1108/BL-01-2022-0001.

Al-Hattami, H.M. (2022) 'Impact of AIS success on decision-making effectiveness among SMEs in less developed countries', *Information Technology for Development*, pp.1–21, https://doi.org/10.1080/02681102.2022.2073325.

Al-Hattami, H.M. and Kabra, J.D. (2022) 'The influence of accounting information system on management control effectiveness: the perspective of SMEs in Yemen', *Information Development*, https://doi.org/10.1177/02666669221087184.

Alkhaldi, R.Z. and Abdallah, A.B. (2019) 'Lean management and operational performance in health care', *International Journal of Productivity and Performance Management*, Vol. 69, No. 1, pp.1–21, https://doi.org/10.1108/IJPPM-09-2018-0342.

Al-Sa'di, A.F., Abdallah, A.B. and Dahiyat, S.E. (2017) 'The mediating role of product and process innovations on the relationship between knowledge management and operational performance in manufacturing companies in Jordan', *Business Process Management Journal*, Vol. 23, No. 2, pp.349–376, https://doi.org/10.1108/BPMJ-03-2016-0047.

Al-Shboul, M.A.R., Barber, K.D., Garza-Reyes, J.A., Kumar, V. and Abdi, M.R. (2017) 'The effect of supply chain management practices on supply chain and manufacturing firms' performance', *Journal of Manufacturing Technology Management*, Vol. 28, No. 5, pp.577–609. https://doi.org/10.1108/JMTM-11-2016-0154.

Al-Swidi, A.K., Al-Hakimi, M.A., Gelaidan, H.M., and Al-Temimi, S.K.A.J. (2022) 'How does consumer pressure affect green innovation of manufacturing SMEs in the presence of green human resource management and green values? A moderated mediation analysis', *Business Ethics, the Environment and Responsibility*, Vol. 31, No. 3, pp.1–23, https://doi.org/10.1111/beer.12459.

Amit, R. and Schoemaker, P.J. (1993) 'Strategic assets and organizational rent', *Strategic Management Journal*, Vol. 14, No. 1, pp.33–46, https://doi.org/10.1002/smj.4250140105.

Amundson, S.D. (1998) 'Relationships between theory-driven empirical research in operations management and other disciplines', *Journal of Operations Management*, Vol. 16, No. 4, pp.341–359, https://doi.org/10.1016/S0272-6963(98)00018-7.

AP, A., EK, A., Nm, I. and Ee, I. (2020) 'Lean management and performance of telecommunication firms: the mediating role of workplace structure', *Cogent Business and Management*, Vol. 7, No. 1, pp.1–20, https://doi.org/10.1080/23311975.2020.1761637.

Arumugam, V., Kannabiran, G. and Vinodh, S. (2020) 'Impact of technical and social lean practices on SMEs' performance in automobile industry: a structural equation modelling (SEM) analysis', *Total Quality Management and Business Excellence*, pp.1–27, https://doi.org/10.1080/14783363.2020.1791067.

Bagozzi, R.P. and Yi, Y. (1988) 'On the evaluation of structural equation models', *Journal of the Academy of Marketing Science*, Vol. 16, No. 1, pp.74–94, https://doi.org/10.1007/BF02723327.

Barney, J. (1991) 'Firm resources and sustained competitive advantage', *Journal of Management*, Vol. 17, No. 1, pp.99–120, https://doi.org/10.1177/014920639101700108.

Barney, J.B. (1995) 'Looking inside for competitive advantage', *Academy of Management Perspectives*, Vol. 9, No. 4, pp.49–61, https://doi.org/10.5465/ame.1995.9512032192.

Belekoukias, I., Garza-Reyes, J.A. and Kumar, V. (2014) 'The impact of lean methods and tools on the operational performance of manufacturing organizations', *International Journal of Production Research*, Vol. 52, No. 18, pp.5346–5366, https://doi.org/10.1080/00207543.2014.903348.

Bhasin, S. (2012) 'Performance of lean in large organisations', *Journal of Manufacturing Systems,* Vol. 31, No. 3, pp.349–357, https://doi.org/10.1016/j.jmsy.2012.04.002.

Black, J.A. and Boal, K.B. (1994) 'Strategic resources: traits, configurations and paths to sustainable competitive advantage', *Strategic Management Journal*, Vol. 15, No. S2, pp.131–148, https://doi.org/10.1002/smj.4250151009.

Bortolotti, T., Boscari, S. and Danese, P. (2015) 'Successful lean implementation: organizational culture and soft lean practices', *International Journal of Production Economics*, Vol. 160, pp.182–201, https://doi.org/10.1016/j.ijpe.2014.10.013.

Buer, S.V., Semini, M., Strandhagen, J.O. and Sgarbossa, F. (2021) 'The complementary effect of lean manufacturing and digitalisation on operational performance', *International Journal of Production Research*, Vol. 59, No. 7, pp.1976–1992, https://doi.org/10.1080/00207543.2020.1790684.

Chand, M., Suraj, and Mishra, O.P. (2019) 'Analysis of lean practices in manufacturing industries: an ISM approach', *International Journal of Six Sigma and Competitive Advantage*, Vol. 11, No. 1, pp.73–94.

Chavez, R., Gimenez, C., Fynes, B., Wiengarten, F. and Yu, W. (2013) 'Internal lean practices and operational performance', *International Journal of Operations and Production Management*, Vol. 33, No. 5, pp.562–588, https://doi.org/10.1108/01443571311322724.

Chavez, R., Yu, W., Jacobs, M., Fynes, B., Wiengarten, F. and Lecuna, A. (2015) 'Internal lean practices and performance: the role of technological turbulence', *International Journal of Production Economics*, Vol. 160, pp.157–171, https://doi.org/10.1016/j.ijpe.2014.10.005.

Colbert, B.A. (2004) 'The complex resource-based view: implications for theory and practice in strategic human resource management', *Academy of Management Review*, Vol. 29, No. 3, pp.341–358, https://doi.org/10.5465/amr.2004.13670987.

Cua, K.O., McKone, K.E. and Schroeder, R.G. (2001) 'Relationships between implementation of TQM, JIT, and TPM and manufacturing performance', *Journal of Operations Management*, Vol. 19, No. 6, pp.675–694, https://doi.org/10.1016/S0272-6963(01)00066-3.

Deshmukh, M., Gangele, A., Gope, D.K. and Dewangan, S. (2022) 'Study and implementation of lean manufacturing strategies: a literature review', *Materials Today: Proceedings*, pp.1–9, https://doi.org/10.1016/j.matpr.2022.02.155.

Deshmukh, S.V. and Lakhe, R.R. (2009) 'An innovative model of Six Sigma for SMEs: the T-DMAIC model', *International Journal of Six Sigma and Competitive Advantage*, Vol. 5, No. 2, pp.187–203.

Devaraj, S., Krajewski, L. and Wei, J.C. (2007) 'Impact of eBusiness technologies on operational performance: the role of production information integration in the supply chain', *Journal of Operations Management*, Vol. 25, No. 6, pp.1199–1216, https://doi.org/10.1016/j.jom.2007.01.002.

Dora, M., Kumar, M., Van Goubergen, D., Molnar, A. and Gellynck, X. (2013) 'Operational performance and critical success factors of lean manufacturing in European food processing SMEs', *Trends in Food Science and Technology*, Vol. 31, No. 2, pp.156–164, https://doi.org/10.1016/j.tifs.2013.03.002.

Dossou, P.E., Torregrossa, P. and Martinez, T. (2022) 'Industry 4.0 concepts and lean manufacturing implementation for optimizing a company logistics flows', *Procedia Computer Science*, Vol. 200, pp.358–367, https://doi.org/10.1016/j.procs.2022.01.234.

Farris, J.A., Van Aken, E.M., Doolen, T.L. and Worley, J. (2009) 'Critical success factors for human resource outcomes in Kaizen events: an empirical study', *International Journal of Production Economics*, Vol. 117, No. 1, pp.42–65, https://doi.org/10.1016/j.ijpe.2008.08.051.

Fornell, C. and Larcker, D.F. (1981) 'Structural equation models with unobservable variables and measurement error: Algebra and statistics', *Journal of Marketing Research*, Vol. 18, No. 2, pp.382–388, https://doi.org/10.1177/002224378101800313.

Furlan, A., Vinelli, A. and Dal Pont, G. (2011) 'Complementarity and lean manufacturing bundles: an empirical analysis', *International Journal of Operations and Production Management*, Vol. 31, No. 8, pp.835–850, https://doi.org/10.1108/01443571111153067.

Gadenne, D. and Sharma, B. (2009) 'An investigation of the hard and soft quality management factors of Australian SMEs and their association with firm performance', *International Journal of Quality and Reliability Management*, Vol. 26, No. 9, pp.865–880, https://doi.org/10.1108/02656710910995064.

Gebeyehu, S.G., Abebe, M. and Gochel, A. (2022) 'Production lead time improvement through lean manufacturing', *Cogent Engineering*, Vol. 9, No. 1, pp.1–15, https://doi.org/10.1080/23311916.2022.2034255.

Goaill, M.M. and Al-Hakimi, M.A. (2021) 'Does absorptive capacity moderate the relationship between entrepreneurial orientation and supply chain resilience?', *Cogent Business and Management*, Vol. 8, No. 1, pp.1–19, https://doi.org/10.1080/23311975.2021.1962487.

Godinho Filho, M., Ganga, G.M.D. and Gunasekaran, A. (2016) 'Lean manufacturing in Brazilian small and medium enterprises: implementation and effect on performance', *International Journal of Production Research*, Vol. 54, No. 24, pp.7523–7545, https://doi.org/10.1080/00207543.2016.1201606.

Habidin, N.F., Hibadullah, S.N., Mohd Fuzi, N., Salleh, M.I. and Md Latip, N.A. (2018) 'Lean manufacturing practices, ISO 14001, and environmental performance in Malaysian automotive suppliers', *International Journal of Management Science and Engineering Management*, Vol. 13, No. 1, pp.45–53, https://doi.org/10.1080/17509653.2017.1288587.

Hackman, J.R. and Wageman, R. (1995) 'Total quality management: Empirical, conceptual, and practical issues', *Administrative Science Quarterly*, Vol. 40, No. 2, pp.309–342, https://doi.org/10.2307/2393640.

Hadid, W. and Mansouri, S.A. (2014) 'The lean-performance relationship in services: a theoretical model', *International Journal of Operations and Production Management*, Vol. 34, No. 6, pp.750–785, https://doi.org/10.1108/ijopm-02-2013-0080.

Hadid, W., Mansouri, S.A. and Gallear, D. (2016) 'Is lean service promising? A socio-technical perspective', *International Journal of Operations and Production Management*, Vol. 36, No. 6, pp.618–642, https://doi.org/10.1108/IJOPM-01-2015-0008.

Hair, J.F., Ringle, C.M. and Sarstedt, M. (2011) 'PLS-SEM: indeed a silver bullet', *Journal of Marketing Theory and Practice*, Vol. 19, No. 2, pp.139–151, http://dx.doi.org/10.2753/MTP1069-6679190202.

Hayes, A.F. (2018) *Introduction to Mediation, Moderation, and Conditional Process Analysis: a Regression-Based Approach,* Guilford Publications, NY.

Hernandez-Matias, J.C., Ocampo, J.R., Hidalgo, A. and Vizan, A. (2019) 'Lean manufacturing and operational performance: interrelationships between human-related lean practices', *Journal of Manufacturing Technology Management*, Vol. 31, No. 2, pp.217–235, https://doi.org/10.1108/JMTM-04-2019-0140.

Hines, P., Holweg, M. and Rich, N. (2004) 'Learning to evolve: a review of contemporary lean thinking', *International Journal of Operations and Production Management*, Vol. 24, No. 10, pp.994–1011, https://doi.org/10.1108/01443570410558049.

Honda, A.C., Bernardo, V.Z., Gerolamo, M.C. and Davis, M.M. (2018) 'How lean six sigma principles improve hospital performance', *Quality Management Journal*, Vol. 25, No. 2, pp.70–82, https://doi.org/10.1080/10686967.2018.1436349.

Hong, P., Yang, M.G.M. and Dobrzykowski, D.D. (2014) 'Strategic customer service orientation, lean manufacturing practices and performance outcomes', *Journal of Service Management*, Vol. 25, No. 5, pp.699–723, http://doi.org/10.1108/JOSM-12-2013-0355.

Jeffers, P.I., Muhanna, W.A. and Nault, B.R. (2008) 'Information technology and process performance: an empirical investigation of the interaction between IT and non-IT resources', *Decision Sciences*, Vol. 39, No. 4, pp.703–735, https://doi.org/10.1111/j.1540-5915.2008.00209.x.

Jun, M., Cai, S. and Shin, H. (2006) 'TQM practice in maquiladora: antecedents of employee satisfaction and loyalty', *Journal of Operations Management,* Vol. 24, No. 6, pp.791–812, https://doi.org/10.1016/j.jom.2005.09.006.

Kamble, S., Gunasekaran, A. and Dhone, N.C. (2020) 'Industry 4.0 and lean manufacturing practices for sustainable organisational performance in Indian manufacturing companies', *International Journal of Production Research*, Vol. 58, No. 5, pp.1319–1337, https://doi.org/10.1080/00207543.2019.1630772.

Ketokivi, M. and Schroeder, R. (2004a) 'Manufacturing practices, strategic fit and performance: a routine-based view', *International Journal of Operations and Production Management*, Vol. 24, No. 2, pp.171–191, https://doi.org/10.1108/01443570410514876.

Ketokivi, M. and Schroeder, R. (2004b) 'Perceptual measures of performance: fact or fiction?', *Journal of Operations Management*, Vol. 22, No. 3, pp.247–264, https://doi.org/10.1016/j.jom.2002.07.001.

Khanchanapong, T., Prajogo, D., Sohal, A.S., Cooper, B.K., Yeung, A.C. and Cheng, T.C.E. (2014) 'The unique and complementary effects of manufacturing technologies and lean practices on manufacturing operational performance', *International Journal of Production Economics*, Vol. 153, pp.191–203, https://doi.org/10.1016/j.ijpe.2014.02.021.

Klein, L.L., Vieira, K.M., Feltrin, T.S., Pissutti, M. and Ercolani, L.D. (2022) 'The influence of lean management practices on process effectiveness: a quantitative study in a public institution', *SAGE Open*, Vol. 12, No. 1, pp.1–14, https://doi.org/10.1177/21582440221088837.

Koh, S. L., Demirbag, M., Bayraktar, E., Tatoglu, E. and Zaim, S. (2007) 'The impact of supply chain management practices on performance of SMEs', *Industrial Management and Data Systems*, Vol. 107, No. 1, pp.103–124, https://doi.org/10.1108/02635570710719089.

Krejcie, R.V. and Morgan, D.W. (1970) 'Deermining sample size for research activities', *Educational and Psychological Measurement*, Vol. 301, pp.607–610, https://doi.org/10.1177/001316447003000308.

Lewis, W.G., Pun, K.F. and Lalla, T.R.M. (2006) 'Exploring soft versus hard factors for TQM implementation in small and medium-sized enterprises', *International Journal of Productivity And Performance Management*, Vol. 55, No. 7, pp.539–554, https://doi.org/10.1108/17410400610702142.

Lorden, A.L., Zhang, Y., Lin, S-H. and Côté, M.J. (2014) 'Measures of success: the role of human factors in lean implementation in healthcare', *Quality Management Journal*, Vol. 21, No. 3, pp.26–37, https://doi.org/10.1080/10686967.2014.11918394.

MacDuffie, J.P. (1995) 'Human resource bundles and manufacturing performance: organizational logic and flexible production systems in the world auto industry', *ILR Review*, Vol. 48, No. 2, pp.197–221, https://doi.org/10.1177/001979399504800201.

Madsen, D.Ø., Risvik, S. and Stenheim, T. (2017) 'The diffusion of Lean in the Norwegian municipality sector: an exploratory survey', *Cogent Business and Management*, Vol. 4, No. 1, pp.1–25, https://doi.org/10.1080/23311975.2017.1411067.

Mahapatra, S.K., Narasimhan, R. and Barbieri, P. (2010) 'Strategic interdependence, governance effectiveness and supplier performance: a dyadic case study investigation and theory development', *Journal of Operations Management*, Vol. 28, No. 6, pp.537–552, https://doi.rg/10.1016/j.jom.2010.04.001.

Maware, C. and Adetunji, O. (2019) 'Lean manufacturing implementation in Zimbabwean industries: impact on operational performance', *International Journal of Engineering Business Management*, Vol. 11, pp.1–12, https://doi.org/10.1177/1847979019859790.

Milgrom, P. and Roberts, J. (1995) 'Complementarities and fit strategy, structure, and organizational change in manufacturing', *Journal of Accounting and Economics*, Vol. 19, Nos. 2–3, pp.179–208, https://doi.org/10.1016/0165-4101(94)00382-F.

Möldner, A.K., Garza-Reyes, J.A. and Kumar, V. (2020) 'Exploring lean manufacturing practices' influence on process innovation performance', *Journal of Business Research*, Vol. 106, pp.233–249, https://doi.org/10.1016/j.jbusres.2018.09.002.

Montabon, F., Daugherty, P.J. and Chen, H. (2018) 'Setting standards for single respondent survey design', *Journal of Supply Chain Management*, Vol. 54, No. 1, pp.35–41, https://doi.org/10.1111/jscm.12158.

Nawanir, G., Teong, L.K. and Othman, S.N. (2013) 'Impact of lean practices on operations performance and business performance: some evidence from Indonesian manufacturing companies', *Journal of Manufacturing Technology Management*, Vol. 24, No. 7, pp.1019–1050. https://doi.org/10.1108/JMTM-03-2012-0027.

Ohno, T. (1988) *Toyota Production System: Beyond Large-Scale Production*, Productivity Press, Cambridge, MA.

Panwar, A., Jain, R., Rathore, A.P.S., Nepal, B. and Lyons, A.C. (2018) 'The impact of lean practices on operational performance–an empirical investigation of Indian process industries', *Production Planning and Control,* Vol. 29, No. 2, pp.158–169, https://doi.org/10.1080/09537287.2017.1397788.

Peteraf, M.A. (1993) 'The cornerstones of competitive advantage: a resource-based view', *Strategic Management Journal*, Vol. 14, No. 3, pp.179–191, https://doi.org/10.1002/smj.4250140303.

Phan, A.C., Abdallah, A.B. and Matsui, Y. (2011) 'Quality management practices and competitive performance: empirical evidence from Japanese manufacturing companies', *International Journal of Production Economics*, Vol. 133, No. 2, pp.518–529, https://doi.org/10.1016/j.ijpe.2011.01.024.

Pozo, H., Roque da Silva, O. and Tachizawa, T. (2017) 'The influence of performance objectives on the implementation of lean manufacturing practices: an analysis based on strategic groups', *Cogent Business and Management*, Vol. 4, No. 1, pp.1–18, https://doi.org/10.1080/23311975.2017.1405718.

Sahoo, S. (2019) 'Lean manufacturing practices and performance: the role of social and technical factors', *International Journal of Quality and Reliability Management*, Vol. 37, No. 5, pp.732–754, https://doi.org/10.1108/IJQRM-03-2019-0099.

Samson, D. and Terziovski, M. (1999) 'The relationship between total quality management practices and operational performance', *Journal of Operations Management*, Vol. 17, No. 4, pp.393–409, https://doi.org/10.1016/S0272-6963(98)00046-1.

Shah, R. and Ward, P.T. (2003) 'Lean manufacturing: context, practice bundles, and performance', *Journal of Operations Management*, Vol. 21, No. 2, pp.129–149, https://doi.org/10.1016/S0272-6963(02)00108-0.

Shah, R. and Ward, P.T. (2007) 'Defining and developing measures of lean production', *Journal of Operations Management*, Vol. 25, No. 4, pp.785–805, https://doi.org/10.1016/j.jom.2007.01.019.

Shingo, S. and Dillon, A.P. (1989) *A Study of the Toyota Production System: From an Industrial Engineering Viewpoint*, CRC Press, USA.

Sodhi, H.S., Singh, D. and Singh, B.J. (2019) 'An empirical analysis of critical success factors of lean six sigma in Indian SMEs', *International Journal of Six Sigma and Competitive Advantage*, Vol. 11, No. 4, pp.227–252.

Spear, S. and Bowen, H.K. (1999) 'Decoding the DNA of the Toyota production system', *Harvard Business Review*, Vol. 77, pp.96–108.

Tan, K.C., Kannan, V.R. and Narasimhan, R. (2007) 'The impact of operations capability on firm performance', *International Journal of Production Research*, Vol. 45, No. 21, pp.5135–5156, https://doi.org/10.1080/00207540600871269.

Tanriverdi, H. and Venkatraman, N. (2005) 'Knowledge relatedness and the performance of multibusiness firms', *Strategic Management Journal*, Vol. 26, No. 2, pp.97–119, https://doi.org/10.1002/smj.435.

Tripathi, V., Chattopadhyaya, S., Mukhopadhyay, A.K., Sharma, S., Li, C. and Di Bona, G. (2022) 'A sustainable methodology using lean and smart manufacturing for the cleaner production of shop floor management in Industry 4.0', *Mathematics*, Vol. 10, No. 3, pp.1–23, https://doi.org/10.3390/math10030347.

USAID (2020) [online] https://www.usaid.gov/yemen/fact-sheets/economic-growth-recoverylivelihoods-and-agriculture (accessed December 27, 2020).

Womack, J.P. and Jones, D.T. (1996) *Lean Thinking*, Simon and Schuster. New York.

Womack, J.P., Jones, D.T. and Roos, D. (1990) *The Machine that Changed the World*, Simon and Schuster, New York.

World Bank (2015) *The Republic of Yemen: Unlocking the Potential for Economic Growth,* Reports No. 102151-YE, World Bank.

YMIT (2014) *General Report of the Result of the Comprehensive Industrial Survey 2010*, Yemen Ministry of Trade and Industry.

Zahra, S.A. and Das, S.R. (1993) 'Building competitive advantage on manufacturing resources', *Long Range Planning,* Vol. 26, No. 2, pp.90–100, https://doi.org/10.1016/0024-6301(93)90140-B.

Appendix 1

Measurement items

Part 1: Lean manufacturing practices

Please circle the number indicating to what extent you agree/disagree with the following: (1 – strongly disagree, 2 – disagree, 3 – neutral, 4 – agree, and 5 – strongly agree)

Technical lean practices	TLP1	Our firm strives to improve continually the quality of its processes rather than taking a static approach
	TLP2	In our firm, processes are being monitored using statistical process control
	TLP3	Maintenance team regularly checks equipment and supplies to make sure they meet the operating requirements
	TLP4	Our firm immediately replaces defective parts of equipment
	TLP5	Our firm uses advanced techniques for managing its inventory bundle
	TLP6	Our firm's materials are readily available as and when needed and without overstocking
	TLP7	In our firm, production is pulled by the shipment of finished goods
	TLP8	In our firm, production at workstations is pulled by the current demand for the next workstation
	TLP9	Kanban, squares, or containers of signals are used for production control
Human lean practices	HLP1	Our firm management provides personal leadership for quality products
	HLP2	Our firm management creates and communicates a vision focused on quality improvement
	HLP3	We provide cross-functional training for our firm employees
	HLP4	Our firm's employees learn how to perform a variety of tasks
	HLP5	We strive to establish long-term relationships with suppliers
	HLP6	We actively engage suppliers in our quality improvement efforts
	HLP7	Supplier evaluation is done on the total cost purchase and not per unit price
	HLP8	Our firm is in close contact with our customers
	HLP9	Our customers take active participation in existing product improvement and new products development process

HLP10	Our customers share the present and future demand information with our firm
Part 2: Operational performance	
Please circle the number that indicates your opinion about how your firm compares to its competitors in your industry: (5 – superior, 4 – better than average, 3 – average or equal to the competition, 2 – below average, and 1 – poor or low)	
Cost	Unit cost of manufacturing
Quality	Quality conformance
Delivery	On-time delivery performance
Flexibility	Flexibility to change product mix