The complementarity of lean manufacturing practices with importance-performance analysis: how does it leverage inventory performance?

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Abstract: This paper aims to examine the effect of lean manufacturing (LM) implementation on inventory minimisation (IM) directly and indirectly [i.e., through manufacturing flexibility (MF) as a mediating variable]. This empirical study used a survey-based quantitative data through a cross-sectional research design and stratified random sampling technique for sample selection. A total of 236 large manufacturing companies were participated in the study. Four hypotheses were tested statistically by applying structural equation modelling (SEM) with Smart PLS 3.2.7. The finding revealed that in order to leverage MF and subsequently augment the inventory performance, LM should be applied in a holistic manner because of the complementary relationships among its practices. The importance-performance map analysis (IPMA) found the LM as the main driver of IM. Despite performing at the comparable level, LM has substantially higher importance than MF. Consequently, performance should be prioritised at the implementation of LM by focusing on the most important constructs of LM (i.e., TPM, quality control, quick setup and flexible resources). This study contributes to filling the existing gaps of limited studies investigating the effect of LM on both MF and IM. The practitioners will be benefited by understanding the vital constructs of LM to improve MF and inventory performance.

Keywords: importance-performance map analysis; IPMA; lean manufacturing; inventory minimisation; manufacturing flexibility.

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1 Introduction

Inventory has a useful function to ensure the availability materials for production and sales. If the inventory is not managed properly, the inventory can be classified as waste and hiding the actual benefits. The optimal control of inventory is one of the greatest challenges faced by firms in a supply chain (Qu et al., 2018). Furthermore, inventory is regarded as one type of waste in a lean manufacturing (LM) system. From the LM perspective, the lower the inventory level will be, the lower the waste exists in the firm (Chen and Tan, 2013). Inventory can make other wastes invisible and untracked. As quoted by Heizer and Render (2011), Shigeo Shingo postulated: “inventory is evil.” He further stated: “if inventory itself is not evil; it hides evil at great cost.” This argument clues that inventory tends to hide multiple problems, abnormalities, and variabilities in the shop floor, and ultimately may incur the extraordinary costs. Several problems, such as lengthy setup, poor quality, elongated process downtime, late delivery, inefficient layout, and unreliable supplier, are tolerated because of maintaining inventory at a high level. Suppliers need to assess a regular progress report at least once every three or four months (Fernando and Wah, 2017). The elimination of inventory exposed the hidden problems. If the problems are resolved, manufacturing processes will run smoothly without other hidden problems and variabilities. This is illustrated by Heizer and Render (2011) with the analogy of water flowing over a bed of rocks. Low inventory levels make a process more dependent on each other. Hence, it quickly reveals problems in the shop floor and gives the worker opportunity to solve the problems.

One of the main reasons of maintaining high level of inventory (i.e., raw materials, work-in-process and finished goods) is the issue of uncertainty, especially demand fluctuation. It is undeniable as the current business situation is characterised by a variety of demand of customers (Metternich et al., 2013), which is almost unavoidable in the today's unpredictable markets. A firm may be challenged to cater a variety of desired products needed by customers. Hagspiel et al. (2016) state that in order to handle the volatile customer's demands, a manufacturer should retain some levels of flexibility to become competitive and profitable. They are undeniably required to be flexible, adaptable, and responsive to the market dynamic changes (Sangwan et al., 2014; Wei et al., 2017). In other words, it is crucial for manufacturers to enhance its ability to respond to a fluctuating demand; they must be able to adapt themselves to dynamic market situations.

Several studies link inventory with LM (Eroglu and Hofer, 2011; Hofer et al., 2012; Zahraee, 2016). The studies found a positive influence of LM implementation on inventory; inventory level is reduced and inventory turnover increases. At the same time, manufacturing flexibility (MF) is also connected with LM (Al-Zu'bi, 2015; Mazanai, 2012; Metternich et al., 2013; Nawanir et al., 2013). Similarly, the studies showed a positive significant effect of LM applications on MF. However, the simultaneous impact of LM implementation on both MF and inventory minimisation (IM) tends to be neglected in previous studies. This paper therefore, aims to examine the effect of LM on IM. The study assumes that LM affects IM directly and indirectly (i.e., through MF as a mediating variable).

To propose the research model, this paper has discussed literature in a couple of ways. Firstly, this paper attempts to provide a clear perspective regarding the effects of LM on IM and MF. It highlights the significance of MF in bridging the impact of LM on IM. Specifically, the study proposes a model examining the intervening role of MF on the link between LM and IM. Secondly, a number of studies (e.g., Furlan et al., 2011a; Khanchanapong et al., 2014; Shah and Ward, 2003) get better understanding of all of the LM elements. Those elements should be implemented simultaneously to gain maximum benefits from its implementation. From lens of a developing country, this paper presents the synergic effect of LM practices on achieving the desired organisational performance (i.e., IM and MF). Lastly, the findings of this paper add to the body of knowledge in the process of examining implications of LM practices with two underpinning theories [e.g., resource-based view (RBV) and complementarity theories]. The findings will benefit the production managers for best practices of LM implementation. The combination of RBV and complementarity theories to explain the LM in practices would strengthen the managers' understanding in achieving the better performance and competitive advantages. The other structure of this paper proceeds with a review of relevant literature, hypotheses' development, theoretical background, and research methodology. Subsequently, the main findings and implications of the study will be presented. Lastly, limitations and suggestions for upcoming research will be addressed.

2 Literature review and hypotheses

The manufacturing firms are not only expected to create products meeting customers' needs for high quality and low price but also provide environmental solutions for consumers and society (Fernando et al., 2016a). The triumph of the Japanese and western manufacturers in achieving an amazing performance has stimulated manufacturers all over the globe to adapt the LM principles. Nowadays, LM has received a considerable attention throughout the world. Undoubtedly, putting LM concept into practices has a profound influence on organisational performance (Chavez et al., 2015; Godinho Filho et al., 2016; Nawanir et al., 2016). The following section will present a review of the existing literature with regards to the concepts of LM, MF and IM. Subsequently, the relationships among the concepts and hypotheses of study are presented.

2.1 LM and complementary relationships among the practices

This paper defines LM as a synergistic approach, aiming at leveraging firms' performance through the elimination of waste. To achieve its objective, a number of its practices must be implemented. LM practices refer to a set of strategic resources used to attain potential benefits of its implementation. Goyal and Deshmukh (1992), Furlan et al. (2011a, 2011b), Mehra and Inman (1992) and White and Prybutok (2001) highlighted the benefits of LM. It would not be grasped until its practices are applied integrally. Considering the results of literature review, this research indicates LM by using the main elements as follows:

- Flexible resources: It is addressed to increase flexibility in a manufacturing system through possessing employees with multiple skills, multi-functional machines and tools, and trainings for multiple tasks (Nawanir et al., 2018a; Russell and Taylor, 2014). The qualified employee will support the inter-department production and service processes (Fernando et al., 2012).
- Cellular layouts: It aims at leveraging flexibility by combining flexibility of a process layout and efficiency of product layout based on the concept of group technology (Finch, 2008; Russell and Taylor, 2014).
- Pull system: It is a concept in which production and material movement are performed when requested, and move to where it is needed just as it is needed, no less, and no more (Heizer and Render, 2011). In order to authorise production and material movement, the use of kanban system is incorporated.
- Small lot production: It is addressed to produce in a small quantity, aiming at achieving the ideal lot size of one (Finch, 2008).
- Quick setups: It aims to reduce the time required to prepare machines or workstations to perform particular jobs (Cheng and Podolsky, 1993; Heizer and Render, 2011; Tersine, 1994). It ensures that shop floor can quickly perform setups if there is a change in process and its requirement.
- Uniform production level: It encompasses production levelling by volume and product types (Chase et al., 2004), which covers activities, such as accurate forecasting, smoothing demand, mixed model production and uniform workload.

- Quality control: It comprises activities, aiming at establishing process and product quality (Fullerton et al., 2003) through identifying defects and drivers. It includes quality at the source, the use of statistical techniques, and trainings for quality control.
- Total productive maintenance (TPM): TPM focuses on leveraging machines and equipment effectiveness with a total system of preventive maintenance involving everyone at all management levels (Imai, 1986).
- Supplier networks: This refers to partnerships between manufacturers and suppliers with a goal of eliminating waste for mutual benefits (Heizer and Render, 2011). It includes JIT delivery by suppliers, suppliers' involvement, long-term relationship with suppliers, and supplier development program.

The study conducted by Nawanir et al. (2013, 2016), Khanchanapong et al. (2014), Shah and Ward (2007) and Hofer et al. (2012) suggested that the LM practices of LM should be adopted integrally as a total system because of the mutual relationship among them. The implementation of one practice may support the employment of others and *vice-versa* (Edgeworth, 1881; Milgrom and Roberts, 1995).

2.2 The relationship between LM and MF

Modern manufacturing has faced challenges in managing business resources and ensure sustainability through day-to-day business operations (Fernando et al., 2016b). Manufacturing firms should be flexible to handle market demand. Russell and Taylor (2014) state: "flexibility has become a competitive weapon." Recently, there have been a significant increasing number of firms concentrating to increase flexibility in order to survive in worldwide competition. Generally, Wei et al. (2017) defined flexibility as an ability to respond to change. Change may be related to product, volume, routing, equipment, labour and supply (Rogers et al., 2011). It may also reflect firm's agility, adaptability, and responsiveness. The LM with support of a kanban system has statistically improved to authorise production and material movements production line productivity (Nawanir et al., 2018b). Achieving greater MF is one of the critical target areas of LM implementation. However, it seems that there was no consensus regarding the elements of MF to be achieved from LM implementation. Furlan et al. (2011b) assessed flexibility performance in terms of product mix and volume. Cheng and Podolsky (1993) also stated that firms should consider flexibility at four different types: volume, product mix, equipment and employee flexibilities. More extensively, Rogers (2008) specified MF in terms of volume, product mix, routing, machine, worker and supply.

With regard to the previous studies, the present paper employs the following six components of MF because the LM practices proposed in this study tend to affect all the components:

- Volume flexibility: It refers to a capability to change production volume/capacity.
- Product mix flexibility: This is a capability to switch between products, including an ability to quick changeover between current products, modification of the products, and newly designed products.

- Routing flexibility: It is the capability to reroute the production flow for better workload balance and to handle disturbance.
- Flexibility in work assignment to machines: It refers to the ability of assigning different types of operations/jobs to the machines.
- Flexibility in work assignment to production workers: It refers to the ability of assigning different jobs to production workers.
- Supply flexibility: It is the ability of suppliers to alter order quantities, including their ability to deliver products frequently and to expedite orders without increasing lead time and costs.

As one of the objectives of LM is to enhance responsiveness of a company to unpredictable customer demand; through its implementation, manufacturers could increase its ability to respond to changes. Several studies engaged LM to MF. Most of them concluded that the implementation of LM significantly improves MF (Agus and Hajinoor, 2012; Bayo-Moriones et al., 2008; Mackelprang and Nair, 2010). Bhamu and Sangwan (2014) and Chauhan and Singh (2013) revealed that lean manufacturers could grab benefits in terms of workers and machines' flexibility. Taj and Morosan (2011) and Dal Pont et al. (2008) found a significant effect of LM on flexibility, in terms of product mix and volume. In addition, as the flexible resources and cellular layouts are the main practices of LM, the LM implementation may lead to routing flexibility in a production system. Hence, LM improves MF. It leads to the following hypotheses:

H_1 There is a positive effect of LM on MF.

2.3 The relationship between LM and IM

One of the goals of LM is to minimise waste caused by the existence of inventory. There are certain indicators, which are frequently used to measure inventory performance, such as inventory turnover (Fullerton and Wempe, 2009; Mackelprang and Nair, 2010) and inventory levels (Bhasin, 2008; Claycomb et al., 1999). Taj (2005, 2008) also stated that inventory level and inventory turnover, are two common measures of inventory performance. Inventory level is frequently indicated in terms of raw materials, WIPs and finished goods.

Inventory turnover refers to the cycle of using and replacing goods in inventory (Tersine, 1994). It indicates the ratio of average cost of goods sold to average inventory value, which shows how frequent the inventory is sold in a year. Costs of goods sold are costs incurred to make a product, including direct labour, direct material and factory overhead. Inventory value is defined as the accumulated monetary value (in dollar) for the year of all categories of inventory. Therefore, inventory turnover ratio should be high, because the higher the inventory turnover ratio, the more efficient the inventory. However, according to Stevenson (2012), inventory turnover is contingent on categories of industry and profit margin of the item. The higher the profit margin, the lower the expected inventory turnover of the items, and *vice-versa*. In addition, the items that require a long time to manufacture, or to sell tend to have low inventory turnover rate.

Other than the reduction of inventory level and inventory turnover, it is essential to include other measures to indicate inventory performance, such as reduction in storage space requirement (Gurumurthy and Kodali, 2009), and reduction in over production

(Garbie, 2010; Wong et al., 2009). It is well-known that the primary implication of LM is IM (Bhasin, 2008; Claycomb et al., 1999) while increasing inventory turnover (Fullerton and Wempe, 2009; Huson and Nanda, 1995; Mackelprang and Nair, 2010). Balakrishnan et al. (1996) suggested that LM adoption was commonly associated with a reduction of inventory levels and an increase in inventory turnover. Literature review indicates that IM can be achieved by ensuring all the required materials that are produced in the just-in-time manner. All practices of LM proposed in the current study are estimated to have a direct influence on inventory performance. Thus, the facts and figures tend to support the following hypotheses:

H_2 There is a positive effect of LM on IM.

2.4 The relationship between MF and IM

There are several ways of improving inventory performance through increasing MF. For instance, machine flexibility may reduce inventory levels (Rogers, 2008) because the flexible machines could be used to perform several functions. Similarly, flexible workers and equipment could prevent the production system from maintaining high level of inventory because the workers and equipment are able to perform multiple tasks and could be quickly switched over to make a different type of products to adapt the customer demand fluctuations and environment uncertainty. On the top of that, workers and equipment flexibility could reduce setup times, throughput times, increase the utilisation of machines as well as the production line productivity, which ultimately could reduce inventory levels (Koste et al., 2004). IM could also be supported by worker flexibility, which enables the production system to increase the options of transferring workers between the tasks because of their overlapping knowledge. This allows the factory to increase the output of products without increasing inventory level because multi-skilled workers can quickly adapt to product modifications and new product developments (Rogers et al., 2011).

More importantly, routing flexibility could reduce setup time, throughput time, and increase the utilisation of machines and equipment. Ultimately, inventory level (in terms of WIPs) could be minimised (Rogers, 2008; Sethi and Sethi, 1990). Moreover, supply flexibility should also reduce inventory levels (Rogers, 2008) through increasing the ability of suppliers in serving the manufacturer in the JIT basis. Based on the literature, there is a consensus among the scholars that MF leads to IM. Thus, the following hypothesis is posited:

H_3 There is a positive effect of MF on IM.

2.5 The mediating Effect of MF

Based on the literature review, a mediation model is proposed in this study, including LM as an independent variable, IM as a dependent variable, and MF as a mediating variable. Specifically, this study assumes the direct and indirect effects of LM on IM through MF as a mediating variable. The subsequent hypothesis is formulated:

H_4 MF mediates the relationship between LM and IM.

3 Methodology

This cross-sectional study involves different companies and investigates a number of dissimilar factors at once, differs across the companies (Easterby-Smith et al., 2008). Measurement of LM was adopted from Nawanir et al. (2015), whereas MF's measurement items were adapted from several different sources, such as Nawanir et al. (2013), Boyle and Scherrer-Rathje (2009), Rogers et al. (2011), etc. In addition, the IM measures were adapted from Fullerton and Wempe (2009), Nawanir et al. (2013), Hofer et al. (2012), etc. The perceptual six-point interval scale from strongly disagree (1) to strongly agree (6) was used in the study.

The population of the study was large manufacturing firms in Indonesia, with a number of employees more than 100. It was rationalised by the studies conducted by Shah and Ward (2007) and Susilawati et al. (2011), which stated that LM was more likely to be applied in large companies than SMEs. In addition, the companies implementing the discrete process (i.e., job shop, batch, repetitive and mass customisation) were selected to abridge the generalisation of findings as well as to avoid bias caused by different implementation of LM practices in the non-discrete process industries.

Using the cluster random sampling procedure, the samples were selected from 3,091 firms listed in the directory of BPS-Statistics Indonesia (2010). 1,000 survey booklets were mailed to the respondents (i.e., middle or top management in production), who are knowledgeable with production activities and company's performance. A stamped self-addressed envelope was included to return the completed booklet.

4 Results

Data were analysed by using structural equation modelling (SEM) with Smart PLS 3.2.7 (Ringle et al., 2015). The two-stage approach suggested by Hair et al. (2017) was applied. Since this study is a confirmatory research, the consistent PLS algorithm was applied to assess measurement model. Subsequently, the hypothesised relationships were assessed by using consistent bootstrapping (Dijkstra and Henseler, 2015a, 2015b). The use of the consistent PLS path modelling approach was rationalised in order to make path coefficient, inter-construct correlations, and indicator loadings become consistent with a factor-model (Dijkstra and Henseler, 2015b).

4.1 Respondent profile

A total of 253 responses were received after data collection within four months, leading to 25.30% effective response rate. Out of the 253 responses, 17 were unusable because of either incomplete answers or outliers. Thus, 236 samples were usable for the subsequent data analysis. The details of respondents' profile are presented in Table 1.

Table 1 Respondents profile

	Count	*%*
Business nature		
Electrical machinery and equipment	21	8.90%
Furniture	32	13.56%
Machinery and equipment	19	8.05%
Instrumentation	7	2.97%
Motor vehicles, trailers/semi-trailers	16	6.78%
Other transport equipment	14	5.93%
Electronics	15	6.36%
Tanning and dressing of leather	12	5.08%
Textiles, wearing apparel	83	35.17%
Wood, products of wood (except furniture)	17	7.20%
Type of production process		
Batch	64	27.12%
Job shop	32	13.56%
Mass customisation	64	27.12%
Repetitive	76	32.20%
Position of respondents in company		
Head of department	44	18.64%
Director	21	8.90%
Manager	158	66.95%
Other middle management position in production	13	5.51%
Total	236	100%

4.2 Measurement model assessment

In the measurement model, two types of validity were assessed (i.e., convergent and discriminant validity). Convergent validity addresses the degree to which the multiple measurement items of a particular construct (or multiple first order constructs of a second order construct) join together and share a high amount of variance (Hair et al., 2017). Three indicators of convergent validity are outer loadings, average variance extracted (AVE) and composite reliability (CR). Outer loadings refer to an estimated relationship in the reflective measurement models, which indicate the items' absolute contribution to its assigned construct (Hair et al., 2017). As shown in Table 2, all the outer loadings are greater than 0.60 and significant at 0.05, indicating that all the items have sufficient contributions on their particular construct. Correspondingly, all the first order constructs (i.e., LM practices) also have adequate loadings on their second order construct LM.

AVE representing the degree to which a latent construct explains the variance of its indicators (measurement items) should go above the suggested value of .50 (Hair et al., 2017). In the second order construct, AVE indicates the variance in the first order construct accounted for by the second order construct. Table 2 shows that the AVE values of the first order constructs are higher than the cut-off value. In addition, CR signifies the internal consistency or homogeneity of the measurement items in the first order construct. Similarly, CR indicates the homogeneity of the first order constructs in their specific second order construct. Table 2 shows that CR values of all the constructs (first and second order) exceed the benchmark value of 0.70 as recommended by Hair et al. (2017). Thus, the model has a sufficient convergent validity.

Table 2 Convergent validity

Construct	*Range of outer loading*	*AVE*	*CR*
First order construct			
Cellular layouts – CL (8)	0.758–0.870	0.681	0.945
Flexible resources – FR (8)	0.619–0.967	0.685	0.937
Pull system – PS (6)	0.798–0.907	0.751	0.947
Quality control – QC (8)	0.785–0.850	0.663	0.940
Quick setups – QS (7)	0.748–0.840	0.614	0.917
Small lots production – SLP (7)	0.808–0.896	0.752	0.955
Supplier network – SN (7)	0.803–0.859	0.705	0.944
TPM (7)	0.807–0.875	0.711	0.945
Uniform production level – UPL (7)	0.687–0.925	0.663	0.932
Inventory minimisation – IM (7)	0.762–0.927	0.705	0.943
Manufacturing flexibility – MF (6)	0.759–0.856	0.677	0.926
Second order construct			
Lean manufacturing – LM (9)	0.668–0.908	0.680	0.950

Note: Numbers in parentheses indicate number of measurement items.

Table 3 Discriminant validity: HTMT statistics

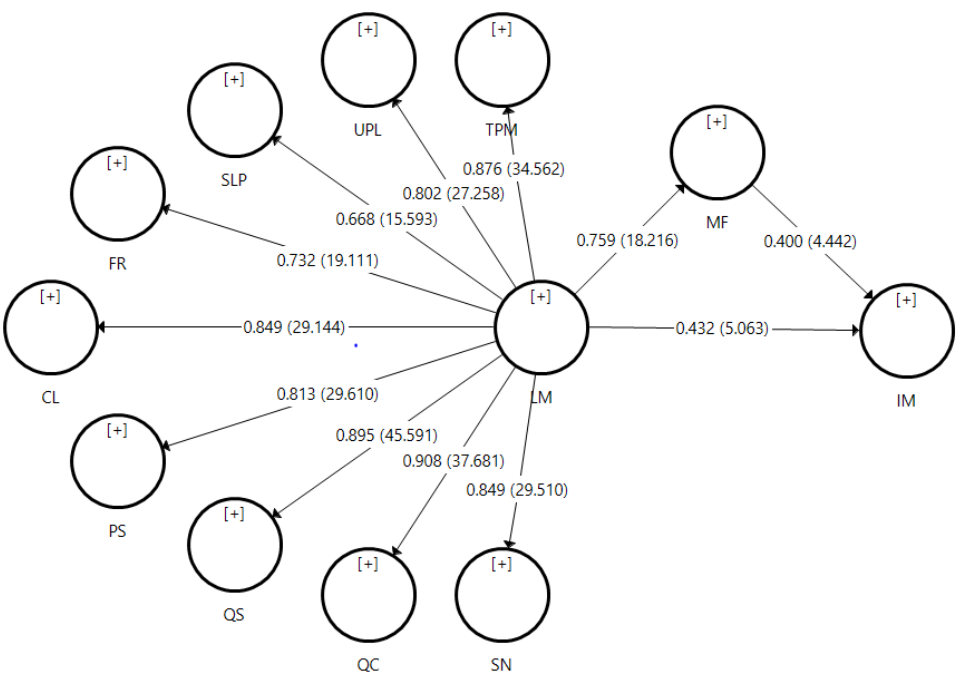
	CL	*FR*	*IM*	*MF*	*PS*	*QC*	*QS*	*SLP*	*SN*	*TPM*	*UPL*
CL											
FR	0.554										
IM	0.565	0.486									
MF	0.631	0.618	0.726								
PS	0.687	0.540	0.520	0.634							
QC	0.693	0.572	0.660	0.658	0.640						
QS	0.736	0.584	0.614	0.662	0.616	0.817					
SLP	0.467	0.428	0.510	0.450	0.539	0.464	0.489				
SN	0.606	0.548	0.664	0.657	0.652	0.787	0.677	0.505			
TPM	0.692	0.516	0.698	0.664	0.616	0.821	0.781	0.459	0.713		
UPL	0.613	0.542	0.588	0.528	0.598	0.630	0.668	0.567	0.563	0.621	

The discriminant validity representing the uniqueness of a construct from other constructs (Hair et al., 2014) was subsequently assessed. It indicates the uniqueness of a construct and its distinction from other constructs. The heterotrait-monotrait (HTMT) ratio (Henseler et al., 2015), which refers to the ratio of the between-trait correlations to the within-trait correlations, was used in this study. In other words, HTMT is the average correlations of indicators across constructs measuring different constructs (heterotrait-heteromethod correlations) relative to the average correlations of indicators measuring the same constructs (monotrait-heteromethod correlations) (Hair et al., 2016). HTMT.85 is used as a guideline to judge discriminant validity as it is regarded as the most conservative criterion (Henseler et al., 2015). As reported in Table 3, HTMT statistics is less than the benchmark value of 0.850 (Henseler et al., 2015). In addition, the test of statistical HTMT inference indicating the 90% normal bootstrap confidence interval of the HTMT criterion does not contain the value of one (Henseler et al., 2015). Thus, the constructs are empirically distinct indicating sufficient discriminant validity. In summary, based on the convergent and discriminant validity assessment results, the model of the study indicates adequate construct validity.

4.3 Structural model assessment

Structural model assessment aimed to test the hypotheses of the study involving evaluating path coefficient (beta), its corresponding significance level (*t*-values), confidence interval, and contribution of exogenous variable(s) on an endogenous variable (R^2). To generate standard errors and to obtain the *t*-values for path estimates, a consistent bootstrapping with 5,000 resamples was applied. It also derives a 95% bias-corrected bootstrap confidence interval for the hypotheses' testing, which provides additional information regarding the stability of coefficient estimate (Hair et al., 2014).

Figure 1 Hypothesised PLS path model



As exhibited in Figure 1 and Table 4, the relationship between LM and MF is significant ($\beta = 0.759$ and $t = 18.216$) with confidence interval ranging from 0.678 to 0.836, which does not contain zero. This indicates that if LM increases by one standard deviation, then MF will go up by 0.759. Thus, H_1 is supported; the higher the extent of LM implementation, the higher the MF.

Table 4 Structural model assessment results

Hypotheses	*Relationship*	*Std. beta*	*Std. deviation*	*t-value*	*Bias*	*Confidence interval*	*Decision*
H1	LM → MF	0.759	0.042	18.216	0.002	0.678–0.836	Supported
H2	LM → IM	0.432	0.085	5.063	–0.008	0.272–0.606	Supported
H3	MF → IM	0.400	0.090	4.442	0.009	0.190–0.560	Supported
H4	LM → MF → IM	0.304	0.073	4.134	0.008	0.150–0.442	Supported

Note: $^*p < 0.05$.

As shown in Figure 1 and Table 4, the relationship between LM and IM is also significant ($\beta = 0.432$, $t = 5.063$), with 0.272 to 0.606 confidence interval, which does not contain zero. Thus, the hypothesis indicated that the β-value equals to zero should be rejected. This specifies that LM has a positive effect on IM; if the extent of LM implementation increases by one standard deviation, then IM would go up to 0.432. Therefore, H_2 is supported. Subsequently, there is a positive relationship between MF and IM with the standardised β equals to 0.400 and significant *t*-value (i.e., 4.442). Table 4 exhibits that the relationship has a confidence interval between 0.190 and 0.566. This clues that when the level of MF rises by one standard deviation, then IM increases by 0.400. Hence, H_3 is statistically supported; the higher the MF, the higher the inventory performance.

With regard to the assessment on the mediating effect, Hayes (2013), MacKinnon and Fairchild (2009), Preacher and Hayes (2008) and Zhao et al. (2010) suggested that the existence of mediation effects should be determined based on the significance of the product of path *a* (i.e., the effect of LM on MF) and path *b* (i.e., the effect of MF on IM). If the product is significantly different from zero, then mediation or indirect effects do exist within the model. Table 4 indicates that the effect of LM on MF and effect of MF on IM are respectively 0.759 and 0.400, which is statistically significant at 0.05 level (one-tailed). Thus, the β-value of the indirect effect of LM on IM is 0.304 (i.e., 0.759 × 0.400), *t*-value = 4.134, and confidence interval between 0.150 and 0.442. Thus, the hypothesis indicating no indirect relationship between LM and IM can be rejected. Hence, the indirect effect is statistically significant at 0.05 level (two-tailed).

The assessment results indicate that direct relationship between LM and IM is positively significant albeit the presence of MF as a mediating variable. Considering this fact and supported by the significant standardised indirect effect, the model fulfils the criteria of complementary mediation (Zhao et al., 2010), in which both indirect effect and direct effect exist and point at the positive direction. It clues that LM positively affects IM in both direct and indirect manners. Hence, the last hypothesis (H_4) is supported; MF complementary mediates the relationship between LM and IM.

The contribution of exogenous variable to the endogenous variable is indicated R^2 values. The standardised estimate of the structural model illustrated that around 57.70% of the variance of MF is explained by LM. Furthermore, both LM and MF explain 60.90% of the variance of IM. In addition, the predictive relevance (Q^2) resulted from blindfolding procedure indicates that the model has a sufficient ability to predict the endogenous variable. Q^2 values for MF and IM are 0.357 and 0.389, respectively. According to Hair et al. (2016), since the values of Q^2 are greater than 0, the model has a good predictive relevance.

4.4 Importance-performance map analysis

In order to obtain deeper understanding of the proposed model and provide insights for managerial actions, an importance-performance map analysis (IPMA) was conducted (Hair et al., 2018; Ringle and Sarstedt, 2016). The IPMA assists the scholars to understand the most important contract of criterions (Nawanir et al., 2018b). This assessment combines the analysis of the importance and performance of each variable (i.e., manifest and latent variable) to its targeted construct. Therefore, through this analysis, specific areas for improvement can be identified and addressed. As exhibited in Table 5, the assessment on the latent variable index values and performance indicates that TPM and QC are the most important constructs, while offering the highest performance among other constructs of LM. Even though SLP offers the lowest performance and less importance than others, all the constructs tend to be equally important for IM. In other words, all the LM constructs contribute significantly to the targeted construct IM. This finding tends to support the mutually supportive relationship among the LM practices towards inventory performance.

Table 5 Latent variable index values and performance

Variables	*LV index values*	*LV performances*
CL	4.719	74.389
FR	4.816	76.315
IM	4.543	65.651
LM	4.727	74.534
PS	4.595	71.892
QC	4.946	78.924
QS	4.898	77.955
SLP	3.964	59.279
SN	4.758	75.151
TPM	5.006	80.116
UPL	4.394	67.887
MF	4.715	74.299

The IPMA also exhibits the importance and performance of LM and MF to the IM. The finding shows that the two constructs are important at the different levels. As an independent variable, LM is highly important than MF with the importance levels of 0.709 and 0.345, respectively. However, the performances of the two constructs to the IM are the same (i.e., 74.534 and 74.299, respectively). This hints that LM is the main driver of IM. Despite performing at the comparable level, LM has substantially higher importance than MF. Hence, performance should be prioritised at the implementation of LM by focusing on the most important constructs of LM as depicted in Table 5.

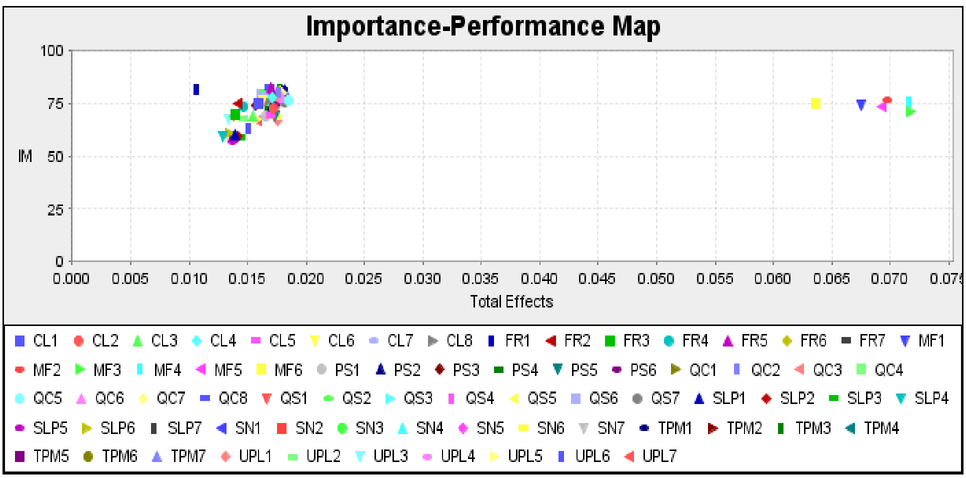
Table 6 Indicators' importance and performance of LM to IM

Item	*CL*	*FR*	*PS*	*QC*	*QS*	*SLP*	*SN*	*TPM*	*UPL*	*MF*
1	0.016 (74.576)	0.011 (81.441)	0.017 (68.729)	0.017 (78.475)	0.016 (75.932)	0.014 (59.746)	0.016 (77.966)	0.018 (81.78)	0.018 (66.610)	0.067 (74.237)
2	0.017 (72.373)	0.014 (75.085)	0.017 (72.881)	0.018 (80.339)	0.016 (80.678)	0.014 (59.576)	0.017 (78.390)	0.017 (79.153)	0.015 (67.627)	0.07 (76.525)
3	0.015 (68.729)	0.014 (69.831)	0.016 (73.983)	0.017 (75.932)	0.016 (74.068)	0.014 (59.153)	0.018 (78.390)	0.018 (81.61)	0.013 (67.542)	0.072 (70.847)
4	0.017 (77.881)	0.015 (73.39)	0.017 (72.458)	0.017 (79.153)	0.016 (79.661)	0.013 (59.407)	0.017 (76.610)	0.018 (79.661)	0.016 (75.169)	0.072 (75.678)
5	0.017 (69.492)	0.017 (82.373)	0.017 (68.983)	0.018 (76.356)	0.017 (80.508)	0.014 (57.034)	0.017 (71.695)	0.018 (76.610)	0.016 (67.542)	0.069 (73.475)
6	0.016 (76.186)	0.014 (69.068)	0.017 (74.237)	0.018 (77.966)	0.016 (78.983)	0.013 (61.102)	0.017 (68.644)	0.018 (80.424)	0.015 (63.390)	0.064 (75.085)
7	0.016 (78.644)	0.017 (79.153)		0.018 (80.169)	0.018 (75.763)	0.014 (59.068)	0.018 (73.559)	0.018 (81.356)	0.016 (67.034)	
8	0.017 (76.525)			0.017 (82.797)						

Note: Values in parentheses are indicators' performance.

In order to gain more specific information on how to minimise inventory, the next analysis will focus on the manifest variables. The results of the analysis on manifest variables are provided in Table 6 and Figure 2. It is found that all the indicators of MF are essential in order to leverage the inventory performance. Thus, in order to minimise inventory, the flexibility of the manufacturing system must increase, in terms of routing, worker, machines, supply, product and volume mix flexibility. When focusing on the LM practices, the importance of the indicators is relatively comparable with each other (ranging from 0.011 to 0.018), while offering some areas for improving inventory performance. Consequently, implementing all the indicators of each LM practice is important to enhance MF and leverage the inventory performance.

Figure 2 Indicators' importance-performance map of the targeted construct IM (see online version for colours)



5 Discussion

As inventory is considered as a cardinal waste in an LM system, one of the main objectives of adopting LM is IM. However, there is a limited evidence supporting the mechanism of how the complementarity practices of LM lead to this performance measure, and which practices are more important to be emphasised in achieving this particular objective. This study aimed at scrutinising the improvement offering by LM implementation on IM by employing MF as a mediating variable. Subsequently, an IPMA was conducted to identify the prioritised areas of improvement in order to gain inventory performance.

The study evidences that LM practices are complementarity constructs. The measurement model and IPMA agreed with each other and led to the same conclusion. LM practices are positively interrelated with one another. Looking at the complementarity theory (Edgeworth, 1881), the finding recommends the simultaneous implementation of all the practices. The theory advocated that the adoption of two complementary practices will leverage the performance of each another. Consequently, the total desired performance tends to be profoundly higher than adopting the practice in a piecemeal approach. On the top of that, the implementation of one practice in isolation without adopting others may even diminish the overall performance of the practices (Tanriverdi, 2005). This finding is consistent with that found by Furlan et al. (2011b), Shah and Ward (2003) and Nawanir et al. (2018a), who proposed the holistic and simultaneous implementation of LM practices.

Inventory was mainly considered as one of the competitive factors. Traditionally, the inventories (e.g., materials and finished goods) are frequently used to prevent the technical core from demand variations. However, the modern production approach considers the existence of inventory as one type of waste. Maintaining inventory is no longer deliberated as a rational to cope with the dynamic environment. Besides costing money, inventory may even reduce the ability of a manufacturing system in response to the environmental uncertainty (Rogers, 2008). In other words, the existence of inventory, to some extent, may negatively affect the MF.

This study found a positive significant effect of LM (as a second order construct) on inventory performance. Countless investigations on the implications of LM on IM have been conducted in the last three decades. Several studies found a significant positive effect of LM implementation on IM. Billesbach and Hayen (1994) stated that JIT implementation improves inventory efficiency. Subsequently, the work of Claycomb et al. (1999) then found a significant negative effect of the total system JIT implementation on inventory level. The higher the degree of JIT implementation, the lower the inbound, in-process, and outbound inventory levels. Zhou (2016) and Jasti and Kodali (2016) have also reported the similar findings. However, the role of MF in improving the inventory performance tends to be neglected in previous studies.

The empirical evidence that MF is affected by the implementation of LM is not unexpected. Within the manufacturing sectors, the increased employment of LM leads to improved MF. This study supports the literature that LM is a foundation for flexible manufacturing (Al-Zu'bi, 2015; Chen and Tan, 2011; Inman et al., 2011). Al-Zu'bi (2015) highlighted the implications of LM implementation on MF in terms of quick response to the dynamic changes of the market requirements. This is because LM practices do not only enable the manufacturers to be flexible in terms of product mix and volume (Metternich et al., 2013), but also flexible in terms of worker, machine, routing and supply (Al-Zu'bi, 2015; Mazanai, 2012; Nawanir et al., 2013).

More importantly, this present study highlighted the importance of MF in mediating the relationship between LM and IM. Besides affecting inventory performance directly, the implication of LM tends to be bridged by the MF. Hence, MF is essential as a pre-existing factor to higher inventory performance. This is because the high ability to cope the environmental uncertainty is one of the benefits of MF; it may lead to a reduction of inventory levels, not only materials, but also WIP and finished goods. Consequently, as the manufacturing system becomes more flexible, maintaining inventory is less required to handle the dynamic environment.

In order to capture the specific areas for improvement, an IPMA was applied. Even though small lot production was indicated to be less important than other practices, the importance of all the practices closely resembles with one another. This advocates the notion of simultaneous implementation of LM practices in order to leverage MF and IM. The IPMA also found out the importance of LM as a main driver of IM. Although MF was found less important than LM, both perform at the comparable level. This indicated that in order to improve inventory performance, LM should be implemented in a holistic manner while attempting to leverage MF in terms of routing, worker, machines, supply, product and volume mix flexibility.

6 Implication of the study

This study has several implications. The implications served as the contribution to the body of knowledge for academia and recommendation to practitioners. Firstly, combining two theories (i.e., RBV and complementarity theories) provided more robust and solid theoretical framework of the study. The use of RBV and complementarity theories implies that LM practices as a set of strategic resources should be implemented concurrently and holistically to enhance the organisational performance (Khanchanapong et al., 2014; Nawanir et al., 2016), especially MF and IM. It means that the implementation of one practice is highly influenced by others, and *vice-versa*. In short, a practice may augment the effect of others. This argument is supported by Milgrom and Roberts (1995) and Tanriverdi (2005), stating that implementing one practice could be ineffective in attaining favoured improvement, which may cause failure (Tanriverdi, 2005). As such, the absence of one practice may adversely affect the implementation of others. Thus, practicing LM in limited subsets potentially brings the company to the unsuccessful implementation and fails to grab the potential benefits of its operation.

Secondly, as this study found a strong connection between LM, MF and IM; it hints how LM cultivates inventory performance. This study evidenced that through MF, LM has a stronger relationship with IM than direct relationship between LM and IM. It articulates the important role of MF as a mediator of the link between LM and IM. This is a valuable evidence about the importance of monitoring MF instead of purely relying on the inventory performance.

Thirdly, as part of managerial implication, this study provides a beneficial viewpoint for manufacturers all over the world to understand and corroborate potential benefits that LM can convey if implemented. The suggestions and ideas provided from this study would help practitioners and managers in steering their companies towards being more competitive. Sustaining LM as a production system is indeed a brilliant choice in order to enhance its performance and competitive advantage. It is hoped that practitioners and other stakeholders can drive the company with actively supporting into LM approach, always searching for ways to eliminate waste, continuously improving the process, and getting employees to live and breathe LM.

7 Limitation and further research

While the main purposes of this study were accomplished, it is necessary to unveil the limitations of the study. The limitations should be considered in terms of construing the results and before taking any necessary arrangements based on its outcomes. First, this study involved large manufacturers categorised under discrete process industries in a single country (i.e., Indonesia). The study of Chen and Tan (2013), Hadid and Mansouri (2014) and Losonci and Demeter (2013) highlighted that LM implementation and its impact on performance might be influenced by contextual factors. Undoubtedly, it would be beneficial to investigate the LM adoption and its effect on flexibility and inventory performance by considering the contextual factors, such as corporate culture, nature of business, company ownership, type of technology used, etc. According to Fernando (2017), the statistical modelling for model optimisation and constructs development. The future study can use robust statistical modelling to examine the impact on the LM practices.

Secondly, this study is a cross-sectional design. As LM is a long-term initiative, and requires a long-term commitment (Jasti and Kodali, 2014), the benefits of its implementation could not be grasped in a short period of time. Given that, implications of LM on flexibility and inventory may be relative at the time of its implementation. Therefore, conducting a longitudinal study would be important to accurately investigate the relationship among the variables. Future study need to incorporate the green operations and sustainability orientation in lean management. This is because green operations and sustainability orientation activities will lead to maintaining lower costs, improving the quality of products, stakeholders' well-being and lowering carbon footprint for greener environments (Fernando et al., 2017).

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