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RESEARCH ARTICLE

DEVELOPING AND VALIDATING MEASUREMENT FOR LEAN MANUFACTURING SUSTENANCE STRATEGIES: THE PLS-SEM APPROACH

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ABSTRACT - Manufacturing worldwide acknowledges lean manufacturing (LM) as a tool to enhance performance. However, sustaining the implementation has been an issue for them to reap the full benefit of LM. With this issue, this study is aimed to investigate the sustaining factors for LM, develop measurement items, provide valid and reliable constructs for LM sustaining factors, and empirically validate the measuring instrument using the SEM approach. Five sustaining factors and 30 assessment items were constructed by adopting, adapting, or self-developing based on the extensive literature review. In total, 151 discrete medium and large manufacturing companies in Malaysia responded to the survey questions. Following that, the constructs were empirically assessed using the SEM model. The findings show that all of the measuring items represent their underlying constructs and contribute significantly to their respective constructs. Some limitations were identified, including the fact that this study was collected from medium and large discrete manufacturing companies in Malaysia, hence resulting in restrictions on generalizability. This research provided valuable information for practitioners to gain more understanding and develop a plan for sustaining LM implementation.

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INTRODUCTION

Manufacturing industries are facing an increase in unpredictability demand and a rapid shift in customer expectations, requiring manufacturers to be more flexible (Koren, 2010). As a result, manufacturers must continue to improve by developing relevant strategies. Many firms worldwide have practiced lean manufacturing (LM) to improve and enhance performance (Loh & Lau, 2019; Sisson & Elshennawy, 2015; Vinodh & Asokan, 2019). LM was introduced in the last two decades, originated from Toyota Production System (TPS), and has become a standard and common approach to manufacturing concepts worldwide (Gunasekaran et al., 2018).

Generally, manufacturers worldwide have been inspired to implement the LM for remarkable performance (Bento & Tontini, 2019; Henrique et al., 2021). Despite clear evidence that shows a relationship between LM and manufacturing excellence, many manufacturers are still battling to keep it going. In any situation, sustaining the implementation of LM is critical. It is crucial for long-term improvement, focusing on achieving continuous operational excellence (Goodyer & Grigg, 2011).

Sustaining the initial benefits of LM implementation has always been viewed as a prominent global challenge. A case study by Grigg et al. (2020) has proven that 90% of the sample failed to sustain LM implementation involving 20 manufacturers in New Zealand. As a result, the researcher must investigate the sustaining elements of LM to reap its benefits. According to Flynn and Scott (2020), different theoretical frameworks are required for these predictors, and the impact of sustainable Lean is uncertain. In addition, it was also stated that LM implementation did not tailor to the situations in which it was presented. Therefore, this research is necessary to better understand the factors supporting the long-term implementation of LM.

This study becomes important because practitioners can use these determinants to gain more rigorous knowledge and better equip themselves to address the challenge of sustaining LM implementation. It can also delegate responsibilities inside the firm to complete the LM implementation. This study is aimed to investigate the sustaining factors for LM, develop the measurement items, and validate the measurement instrument empirically using the data from manufacturing companies in Malaysia. The concept of sustaining factors for LM and the development of constructs will be discussed in this paper. Subsequently, the findings and implications will be examined, and the study will conclude with limitations and recommendations for further research.

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DEFINITION AND DEVELOPMENT OF CONSTRUCT

Gaspar and Leal (2020) defined sustain as continuing a new practice until it has been integrated within an organization. It has become a routine part of the process and continues to provide desired objectives. In addition, the ways of thinking, attitudes, and outcomes have changed. As a result, the new practice has evolved into a new work method. Merriam-Webster dictionary described sustaining as the capability of being continuously maintained at length without depleting or weakening. Similarly, Gaspar and Leal (2020) stated that sustainability is the means for a company to avoid losing momentum from initial gains and reverting to their competitors' growing productivity gap.

On the other hand, LM can be defined as manufacturing practices that aim to reduce waste and maximize value throughout the whole manufacturing value chain. Hence, from these definitions, this study defined sustaining LM as the ability to sustain the LM implementation aimed at eliminating waste, increasing value, and adopting the implementation as a new way of thinking.

Construct definition also entails determining the dimensionality of the conceptual variable, with each dimension representing a different aspect of the conceptual variable. An operational definition is affected by the context in which a conceptual variable is studied, and the definition may differ from one study to another (Hair et al., 2017). Conceptual variable relates to measurable and observable quantities. It also helps understand how conceptual variables are represented by constructs in structural equation models (i.e., latent variables). Constructs are not directly observed but mathematically observed from manifest variables (i.e., items or indicators).

According to Plenert (2012), the primary advantages of sustained LM are lead times reduction, increased efficiency, quality, and productivity. As a result, it is critical and beneficial for the organization that initiates LM to discover strategies to sustain it over time. The advantages of sustaining LM will assist manufacturers in remaining profitable in a highly competitive market and improve overall operations performance.

Lean Leadership

Leadership is the ability to inspire and influence the collective efforts of subordinates to adapt to new transformative changes is the essence of leadership (Sahoo, 2020). LL is defined as attitudes, behaviours, and competencies demonstrating respect for individuals, motivating individuals, and ensuring effective resources (Costa et al., 2019). Leaders will significantly impact the effectiveness of LM by encouraging, coaching, and exchanging ideas with their co-workers, which will be essential to sustain LM (Bose & Sengupta, 2020). Leaders' involvement is crucial to LM's long-term success (Bortolotti et al., 2015). Participating actively in implementing any LM efforts is one of the best ways for leaders to demonstrate their commitment (Siagian et al., 2021). The ideal conditions for LM dissemination must be created to motivate employees, and management must be accountable for encouraging physical and emotional commitment. Involving top management in lean operations will ensure that improvements and actions align with the corporate vision and mission (Alhuraish et al., 2017). Leadership requires a vision and forward-thinking leader, LM is long-term, and it is nothing without visionary leadership thinking behind it (Sahoo, 2020). Coaching to inspire and motivate employees is another aspect of LL. One of the most direct ways to coach is during *gemba genchi genbutsu*, which allows for two-way communication. In addition, top management must have an efficient communication channel through town halls, newsletters, and individual meetings (Udod et al., 2020). Considering this, this study combined LL measurements from previous studies into a collection of common variables listed in Table 1.

Table 1. Lean leadership measurement

Lead Leadership (LL)	Literature
Management Commitment	(Al-Dhaafri & Alosani, 2020; Bortolotti et al., 2015; Cheng, 1989; Comm & Mathaisel, 2005; Cudney et al., 2020; Fernández-Mesa & Alegre, 2015; Foo et al., 2015; Gaspar & Leal, 2020; Goodyer & Grigg, 2011; Henrique et al., 2021; Loh & Lau, 2018; Oly Ndubisi et al., 2005; Sahoo, 2020; Siagian et al., 2021; Udod et al., 2020)
Management Vision & Mission	(Alhuraish et al., 2017; Cheng, 1989; Cudney et al., 2020; Goodyer & Grigg, 2011; Henrique et al., 2021; Oly Ndubisi et al., 2005; Osman et al., 2020; Sahoo, 2020; Siagian et al., 2021; Tezel et al., 2017; Udod et al., 2020)
Management Coaching	(Alhuraish et al., 2017; Cheng, 1989; Cudney et al., 2020; Goodyer & Grigg, 2011; Henrique et al., 2021; Oly Ndubisi et al., 2005; Osman et al., 2020; Sahoo, 2020; Tezel et al., 2017; Udod et al., 2020)
Communication	(Cheng, 1989; Oly Ndubisi et al., 2005; Osman et al., 2020; Osman et al., 2021; Udod et al., 2020)

Lean Culture

Culture is defined broadly as something that exists and substantially impacts (Ojha, 2015). Organizational culture affects organizational performance since it is influenced by individual behavior (Chavez et al., 2015). LC is defined in this study as a shared behavior and attitude that exists and plays a significant role in influencing LM. The challenge in implementing and sustaining LM lies in the organizational culture (Netland et al., 2019). *Kaizen* is a culture that drives changes that leads to operational excellence to sustain LM (Chiarini & Brunetti, 2019). *Gemba* walk exercise is critical in developing *a kaizen culture* to sustain LM improvement (Grigg et al., 2020). It should not require management initiatives to embed an improvement culture; rather, it should come from the individuals in the organization (Comm & Mathaisel, 2005). In creating the step toward *kaizen* culture, the practice of *gemba genchi genbutsu* is suggested. This practice aims to find improvement ideas where the operation is conducted, and the value is created (Tiwari et al., 2020). A long-term LM depends on management and employee commitment to attain long-term benefits. Employee participation and understanding of LM are crucial to its success (Al-Dhaafri & Alosani, 2020). Hence, the LC measurements from past studies were combined in this study into a set of common variables listed in Table 2.

Table 2. Lean culture measurement

Lean Culture (LC)	**Literature**
Employee Commitment	(Al-Dhaafri & Alosani, 2020; Bortolotti et al., 2015; Bose & Sengupta, 2020; Comm & Mathaisel, 2005; Fernández-Mesa & Alegre, 2015; Gaspar & Leal, 2020; Goodyer & Grigg, 2011; Henrique et al., 2021; Hines, 2010; Mabunda, 2019; Oly Ndubisi et al., 2005; Osman et al., 2020; Osman et al., 2021; Sahoo, 2020; Siagian et al., 2021; Udod et al., 2020)
Kaizen	(Flynn & Scott, 2020; Goodyer & Grigg, 2011; Henrique et al., 2021; Hoque et al., 2020; Mano et al., 2021; Oly Ndubisi et al., 2005)
Gemba Genchi Genbutsu	(Foo et al., 2015; Hines, 2010; Oly Ndubisi et al., 2005; Tiwari et al., 2020; Udod et al., 2020)

Lean Supplier Management

Suppliers are important concerns for buyers since they contribute to product efficiency, stability, and cost in the goal of manufacturing excellence (Bose & Sengupta, 2020; Cheng, 1989). Buyers must manage their suppliers to use the capabilities of suppliers entirely (Abdulmalek & Rajgopal, 2007). This study describes LSM as selecting a supplier, establishing a collaborative supplier partnership, and developing a supplier development program to implement LM. The trend toward collaborative supplier relationships is growing, especially among major and worldwide manufacturers looking to optimize delivery, quality, and cost. Collaboration has benefited both relationships regarding cost and reward sharing and shared product growth. Another critical component in sustaining LM implementation is holistically implementing it as a corporate-wide effort. One reason for failure to sustain is when the LM deployment is not spread widely throughout the firm (Siagian et al., 2021). In addition, suppliers should be included in the following sequence to be extended after the organization has effectively implemented LM (Bose & Sengupta, 2020). Toyota has established a long-term supplier relationship and development plan and synchronized its production and delivery schedules. In addition, as part of supplier management, supplier selection based on the capability that leads to operational excellence plays an important role (Bento & Tontini, 2019). Several studies have analyzed the positive relationship between supplier selection activities and manufacturers' performance (Jørgensen et al., 2007). Table 3 depicts the combined measurements of LSM from previous studies.

Table 3. Lean supplier management measurement

Lean Supplier Management (LSM)	**Literature**
Collaborative Partnership	(Bortolotti et al., 2015; Bose & Sengupta, 2020; Cadden et al., 2020; Cheng, 1989; Flynn & Scott, 2020; Henrique et al., 2021; Mano et al., 2021; Sahoo, 2020)
Supplier Development Program	(Mano et al., 2021; Siagian et al., 2021)
Supplier Selection	(Comm & Mathaisel, 2005)

Lean Knowledge Management.

Knowledge is a key source of competitive advantage (Flynn & Scott, 2020). Knowledge management should be included to arrange and coordinate knowledge within the organization (Hoque et al., 2020). Manufacturing failed to keep

LM implementation due to a lack of focus on developing LM capabilities within the organization. Employees can better understand LM while implementing it and create a learning environment that supports lean culture by improving their skills (Foo et al., 2015). External consulting companies specializing in LM and providing expertise in the principles and techniques could provide knowledge and experience in LM (Hoque et al., 2020). According to Udod et al. (2020), many companies have benefited from external lean experts who have provided the employees with the necessary knowledge and experience to implement and sustain their LM. Many researchers have identified inadequate training as one of the major issues threatening the long-term viability of LM (Bose & Sengupta, 2020). According to several researchers, one of the primary issues limiting the long-term implementation of LM is the lack of training (Tiwari et al., 2020). LM initiatives are sustained when the staff is well-trained in lean methods and can put their theoretical knowledge into practice (Fernández-Mesa & Alegre, 2015). Kaizen events are important for practitioners as a great way to drive kaizen and quickly convey lean knowledge (Comm & Mathaisel, 2005). Considering this, this study combined measurements of LKM from previous studies into a collection of common variables listed in Table 4.

Table 4. Lean knowledge management measurement

Lean Knowledge Management (LKM)	Literature
Lean Knowledge and Experience	(Alhuraish et al., 2017; Bortolotti et al., 2015; Bose & Sengupta, 2020; Flynn & Scott, 2020; Gaspar & Leal, 2020; Goodyer & Grigg, 2011; Loh & Lau, 2018; Oly Ndubisi et al., 2005; Udod et al., 2020) (Siagian et al., 2021) (Tezel et al., 2017) (Tiwari et al., 2020)
Regular Training	(Al-Dhaafri & Alosani, 2020; Bose & Sengupta, 2020; Cheng, 1989; Comm & Mathaisel, 2005; Fernández-Mesa & Alegre, 2015; Hoque et al., 2020; Oly Ndubisi et al., 2005; Osman et al., 2020; Sahoo, 2020; Tezel et al., 2017; Tiwari et al., 2020)
Lean Workshop/Event	(Comm & Mathaisel, 2005; Tiwari et al., 2020; Udod et al., 2020)

Lean Resource Management

Resources are valuable assets a person or organization must possess to function properly. There are two types of resources that an organization might have, which are tangible and intangible (Yadav et al., 2018). LM and its sustenance were proposed to use dedicated resources (Siagian et al., 2021). Full-time resources are recommended to attain a satisfactory level of LM implementation (Oly Ndubisi et al., 2005). Dedicated organizations must ensure that LM is sustained, and it proposed that 3% of the organization's capacity should be committed to a lean organization. Furthermore, according to Udod et al. (2020), financial and human resources contribute to the long-term LM. In the efforts to sustain LM, lack of time and a high budget are the common excuses (Cudney et al., 2020). Multi-skilled personnel and flexible tools and equipment are critical to sustaining LM implementation (DeSanctis et al., 2018). To be flexible, workers are involved in multiple tasks to meet customer demands for more variation, higher quality, reliability, and delivery. This flexibility will assist the manufacturers in producing based on the JIT approach to reduce the inventory across the value chain. Considering this, this study combined LRM measurements from previous studies into a collection of common variables listed in Table 5.

Table 5. Lean resource management measurement

Sustaining Factors of LM	Literature
Lean Resource Management (LRM)	
Dedicated Organization	(Bortolotti et al., 2015; Goodyer & Grigg, 2011; Henrique et al., 2021; Oly Ndubisi et al., 2005; Osman et al., 2020; Siagian et al., 2021)
Flexible Resources	(Hines et al., 2020; Ruben et al., 2019)
Financial Resources	(Loh & Lau, 2018; Oly Ndubisi et al., 2005)

METHODOLOGY

A survey approach with closed-ended questionnaires was used to collect data. A survey gathers data to describe, compare, and explain one's knowledge, opinions, or behavior (Fink, 2003). (Fink, 2003). A cross-sectional sample was used in this study. In a cross-sectional study, data were collected at a single time. In total, 50 measurement instruments were created to assess a specific content that had been adopted, adapted, or self-developed based on earlier research. A 5-point interval scale was used as a scale property. Academicians and practitioners examined content validity through pre-testing to eliminate any possible bias. Pre-testing the instrument is crucial to ensure the respondents understand the questions and ensure no ambiguities in the questions, language, and measurement (Mano et al., 2021). As a result, this study conducted a pre-test study with two academicians and three practitioners to ensure content validity.

Respondent feedback was used to improve the instrument and make it better by adding, eliminating, or revising measurement items.

The unit of analysis for this study is organization. At the same time, middle management (i.e., managers) and top management are the elements of the unit of analysis (i.e., The Vice President, Chief Executive Officer, Chief Operation Officer, General Manager, and Senior Manager). A population is a group of humans, events, or things with a common observable attribute (Sekaran & Bougie, 2016). Therefore, the population in this study is discrete manufacturing on Malaysia's medium and large-scale. Therefore, the population in this study is discrete manufacturing in Malaysia's medium and large-scale industries. The list from the Federation of Malaysian Manufacturers (FMM) directory was used to compile a list of all available manufacturers. From the list, a total of 1185 discrete manufacturing companies were identified in the FMM database. Hence, they were chosen as a population. This research is limited to discrete manufacturing since discrete manufacturing is more common than continuous process manufacturing in terms of LM implementation (Abdallah & Alkhaldi, 2019).

The population sample for this study was drawn by using random cluster sampling. The clusters in this study correspond to different types of industries, and each cluster's sample size was calculated proportionally based on the overall population. The study included 172 returned questionnaires, with a response rate of 17.2%. However, due to unrelated manufacturing sectors (i.e., process or continuous manufacturing), 21 replies were excluded from subsequent data analysis, and ineligible respondents completed the survey. Finally, 151 data sets were usable, resulting in an effective response rate of 15.1%. Table 6 shows the background and demographics of 151 respondents, including industry types, respondent positions, years of operation, and years of experience in the organization. Generally, all respondents are eligible to participate in the survey.

Table 6. Respondent profile

Demographics	Sample	
	n	%
Types of Industry		
Transport equipment & other manufacturers	75	49.67
Electrical and electronics	54	35.76
Non-metallic mineral and fabricated metal products	19	12.58
Wood, furniture, paper, and printing	3	1.99
Years of operation		
More than 5 years	129	85.43
Between 2 and 5 years	12	7.95
Less than 2 years	10	6.62
Position in the company		
Manager	114	77.48
Senior/General Manager	27	17.88
Chief Operations	7	4.64
Year of experience in the company		
More than 5 years	65	43.05
Between 3 and 5 years	49	32.45
Less than 3 years	37	24.50

EMPIRICAL ASSESSMENT OF THE CONSTRUCT

PLS-SEM was used in this study due to the exploratory nature of the research (Hair et al., 2017). PLS-SEM through Smart-PLS software was used to analyze the causal relationships between constructs. It can produce sensible results even with little outliers, and the data would not be distorted (Hair et al., 2017). As this study aimed to validate the measurement instrument empirically, the measurement model was examined to test the validity and reliability of the instruments. The validity assessment determines how well a developed instrument assesses a specific concept. It is intended to measure, whereas reliability assesses how consistently a measuring instrument measures the concept (Sekaran & Bougie, 2016). The reflective measurement model is assessed on its validity (i.e., convergent validity and discriminant validity) and reliability (i.e., composite reliability) (Hair et al., 2017).

Convergent validity is used to assess whether or not the constructs that should be linked are proven to be related. Convergent validity is based on the outer loading of the indicators and the average variance extracted (AVE). According to Hair et al. (2017), the loadings should be greater than 0.4, and the AVE should be greater than 0.5. Instead of the widely used methods of Cronbach's alpha, composite reliability (CR) is proposed to quantify internal consistency reliability as

it addresses the limitation of not weighing the individual indicators in the analyses. Hair et al. (2017) proposed values greater than 0.7 for measuring CR. Table 7 summarizes convergent validity, indicating that all constructs are acceptable and above the threshold values.

Table 7. Convergent validity

Construct	Outer Loading	CR	AVE
LL	0.681 - 0.846	0.921	0.625
LC	0.692 - 0.775	0.884	0.561
LSM	0.540 - 0.863	0.888	0.618
LKM	0.758 - 0.828	0.914	0.640
LRM	0.697 - 0.780	0.842	0.571

Discriminant validity is established when two variables are predicted to be uncorrelated, and the scores obtained by measuring the variables are empirically found to be so. Hair et al. (2017) suggested Heterotrait-Monotrait (HTMT) for measuring discriminant validity, arguing that it is completely reliable because it estimates the actual correlation between two constructs if they were perfectly assessed. HTMT result greater than 0.900 indicates a lack of discriminant validity (Hair et al., 2017). Table 8 demonstrates the values for discriminant validity through the HTMT test. The result showed that the HTMT values were less than 0.900, indicating that all constructs were different and did not have interchangeable interpretations.

Table 8. HTMT ratio

	LC	**LKM**	**LL**	**LRM**	**LSM**
LC					
LKM	0.836				
LL	0.803	0.767			
LRM	0.757	0.867	0.751		
LSM	0.723	0.790	0.616	0.549	

DISCUSSION AND CONCLUSION

The objectives of this paper were to identify the factors that sustain LM, develop measurement items, and statistically validate the measuring instrument. Following that, pre-testing was performed to ensure content validity. A measurement model analysis was carried out to establish validity and reliability. Finally, the findings, implications, limitations, and future research proposals will be discussed. A previous study by Fernández-Mesa and Alegre (2015) examined the factors influencing long-term LM implementation. Employee engagement is considered vital in nurturing the LC. Hence it was suggested that LC is a key factor in sustaining LM. LKM is also important because it stimulates employees to participate in LM projects. LL, LSM, and LRM, on the other hand, were not addressed in this study. Goodyer and Grigg (2011) conducted a study on long-term LM implementation. According to reports, LL is crucial in conceptualizing the LM implementation, especially after the lean consultant has left after delivering training and information transfer (i.e., LKM). As a result, it was suggested that the LM implementation should be steered by an internal team (i.e., LRM) to ensure its long-term viability. In addition, culture is essential to sustain LM and encourage it to progress into LC. This research, however, excludes LSM from the spectrum of sustaining factors for LM.

Toyota had developed a long-term supplier relationship and a supplier development plan and had synced its production and delivery schedules. Suppliers should be assisted in growing their skills so that manufacturers will be benefited from their efforts. As far as researchers are aware, a little comprehensive study has been conducted on the sustaining factors for LM. However, manufacturers that have implemented LM faced significant hurdles in sustaining it. The sustaining factors and their measurement items were established due to a thorough literature review. Practitioners and academicians in operations management have evaluated content validity. The researchers have surveyed 151 medium and large discrete manufacturers in Malaysia. The respondents were middle and upper management and were expected to provide an excellent understanding of data collection.

Following that, an empirical evaluation of the sustaining factors of LM (i.e., construct validity and reliability) was performed using an SEM approach. The assessment result showed that all factors (i.e., measurement items) measure their underlying constructs. In other words, all of the items make a considerable contribution to their respective constructs. This study is significant since there is a need to understand, and previous researchers offered little guidance on the predictors of sustainable LM implementation. This is consistent with findings from Fernández-Mesa and Alegre (2015), which emphasized the need for future researchers to understand the determinants of LM sustainability. These predictors require different theoretical frameworks, and the influence of sustainability remains unknown. It is also highlighted that *"lean implementation did not tailor to the contexts in which it had been introduced."*

A thorough review of the literature and a comprehensive assessment by the practitioners and academicians established the content validity of the construct. The constructs were then validated based on a sufficient number of samples. There was sufficient empirical data to establish content validity, construct validity, and construct reliability. As a result, comprehensive and verified measurement constructs of sustaining variables for LM were identified. This study provided a significant tool for academicians to better understand how LM implementation is sustained. The measurement constructs validated in this study are hoped to benefit the practitioners in the sustainability of LM employment in their companies and take feasible steps to improve manufacturing excellence. Although the study was done in the setting of medium and large discrete manufacturers in Malaysia, the measurement development employed in this study might be applied by practitioners and academicians from other manufacturing sectors and countries. The instrument described in this research will positively motivate lean implementation and ensure its sustainability.

Nevertheless, some limitations were recognized during the research process. These limitations should be addressed by future researchers for a more comprehensive investigation. To begin, the sample for this research was obtained from medium and large discrete manufacturing companies in Malaysia. As a result, the generalizability of the result may be restricted. Hence, future research might test this model in different industries and countries to improve the generalizability of the findings. Furthermore, by employing a mixed-method approach, future research might expand the measurement items for this topic. Using both methodologies greatly contribute to providing a holistic perspective and gives a breadth and depth of understanding of phenomena that neither qualitative nor quantitative research approaches could alone complete.

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