

FACTORS INFLUENCING LEAN MANUFACTURING PRACTICES ON PRODUCTION LEAD TIME SUSTAINABILITY

FATORES QUE INFLUENCIAM AS PRÁTICAS DE MANUFATURA ENXUTA NA SUSTENTABILIDADE DO PRAZO DE PRODUÇÃO

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Abstract

For small enterprises and medium enterprises (SMEs) aiming to remain competitive with restricted resources, reducing Production Lead Time (PLT) sustainably counts the most. Tools gleaned from lean manufacturing not only cut waste but also increase efficiency and sustainable growth in productivity. However, the ability to achieve these aims depends on the context in which they are applied and how well they fit with others. The paper examines how the five main daily work tasks or tools in the lean system, such as Value Stream Mapping (VSM), Just-In-Time (JIT), Setup Time Reduction (STR), Employee Involvement (EI), and Layout Redesign (LR), combine to affect PLT in Malaysian SMEs. While previous studies have clearly highlighted the advantages of each step in a large production setup, the advantages for resource-limited, smaller firms remain largely unknown. This quantitative research, guided by Lean Thinking Theory and Socio-Technical Systems Theory, uses structured questionnaires for production and operations managers. The findings aim to offer insight into how completely integrated lean practices can lead to PLT. It provides practical advice for the adoption of leaner production systems.

Resumo

Para pequenas e médias empresas (PMEs) que buscam manter a competitividade com recursos limitados, a redução sustentável do Tempo de Ciclo de Produção (TCP) é fundamental. As ferramentas derivadas da manufatura enxuta não apenas reduzem o desperdício, mas também aumentam a eficiência e promovem o crescimento sustentável da produtividade. No entanto, a capacidade de atingir esses objetivos depende do contexto em que são aplicadas e de como se integram com outras ferramentas. Este artigo examina como as cinco principais tarefas ou ferramentas do sistema enxuto, como Mapeamento do Fluxo de Valor (MFV), Just-In-Time (JIT), Redução do Tempo de Preparação (RTP), Envolvimento dos Funcionários (EF) e Redesenho do Layout (RL), se combinam para afetar o TCP em PMEs da Malásia. Embora estudos anteriores tenham claramente destacado as vantagens de cada etapa em uma grande estrutura de produção, as vantagens para empresas menores com recursos limitados permanecem em grande parte desconhecidas. Esta pesquisa quantitativa, guiada pela Teoria do Pensamento Enxuto e pela Teoria dos Sistemas Sociotécnicos, utiliza questionários estruturados para gerentes de produção e operações. Os resultados visam oferecer



Keywords: Employee Involvement. Just-In-Time. Layout Redesign. Lean Tools. Production Lead-Time. Value-Stream Mapping. Sustainability.

insights sobre como práticas enxutas totalmente integradas podem levar à redução do TCP. Oferece conselhos práticos para a adoção de sistemas de produção mais enxutos.

Palavras-chave: *Envolvimento dos funcionários. Just-in-Time. Redesenho do layout. Ferramentas Lean. Tempo de ciclo de produção. Mapeamento do fluxo de valor. Sustentabilidade.*

1 INTRODUCTION

1.1 Research Background

In lean manufacturing, cutting down on production lead time (PLT) in a sustainable manner directly helps several UN Sustainable Development Goals (UNSDGs), mostly by eliminating waste, using resources more efficiently, and improving working conditions. This method fits well with UNSDG 12 (Responsible Consumption and Production) and UNSDG 8 (Decent Work and Economic Growth) as indicated by Salman et al., (2024). In a dynamic and uncertain global manufacturing environment, minimising PLT has become a fundamental requirement for competitiveness and customer satisfaction. For SMEs operating under resource constraints, achieving shorter PLT is highly critical to maintaining responsiveness and efficiency, heavily depending on contextual practices and integration across tools.

The widely adopted practices include Value Stream Mapping (VSM), Just In Time (JIT), Setup Time Reduction (STR), Employee Involvement (EI), and Layout Redesign (LR). Each tool targets different dimensions of waste generation and elimination, ranging from inventory management to process flow optimisation and workforce engagement. While these practices are well documented in large-scale organisations, empirical studies examining their collective influence on PLT in SMEs remain limited.

In Malaysia, SMEs contribute significantly to national economic growth, accounting for approximately 38% of the GDP and employing nearly 70% of the workforce (SME Corp Malaysia, 2023). SMEs mostly face constrained financial access, insufficient technological infrastructure, and low levels of process standardisation, hindering the implementation of lean initiatives and limiting their effectiveness in

achieving reduced lead times. This study aims to bridge this knowledge gap by exploring how different lean tools interact and influence PLT within Malaysian SMEs.

1.2 Problem Statement

Although lean manufacturing has been recognised as an effective system for operational excellence, its application in SMEs is often unstructured, disconnected and resource constrained.

Previous studies (Gebeyehu, 2022; Bugvi et al., 2021) divulge that SMEs commonly experience challenges, such as disorganised production layouts, limited managerial capability, and inconsistent workforce involvement. Consequently, many SMEs fail to achieve the expected reductions in PLT despite adopting lean tools.

JIT is theoretically designed to synchronise production with demand and minimise inventory-holding time. However, in SMEs, supply chain volatility and limited supplier reliability often weaken JIT's impact of JIT (Dhawan, 2023). Similarly, VSM helps visualise process inefficiencies, yet its benefits are often underutilised in firms lacking technical expertise or cross-departmental integration (Reda & Dvivedi, 2022). Employee involvement, though a key principle of lean culture, may yield limited benefits when organisational hierarchies constrain bottom-up feedback (Mrope & Namusonge, 2022). These inconsistencies suggest that lean tools operate ineffectively in isolation within SMEs, but rather as part of an integrated and context-sensitive system.

This study investigates how five core lean practices—VSM, JIT, STR, EI, and LR—collectively influence PLT in Malaysian SMEs. Understanding these relationships is crucial for identifying which lean practices have the greatest impact on time efficiency and for developing frameworks that enable SMEs to implement lean practices effectively under resource limitations.

1.3 Research Questions

The following questions guide this study:

1. Does Value Stream Mapping contribute to minimising the PLT?
2. Does Just-In-Time contribute to minimising PLT?
3. Does Setup Time Reduction contribute to minimising PLT?

4. Does Employee Involvement contribute to minimising PLT?
5. Does Layout Redesign contribute to minimising PLT?

Research Objectives

Correspondingly, the research objectives are as follows:

1. To determine the relationship between Value Stream Mapping and PLT.
2. To examine the relationship between Just-In-Time and PLT.
3. To analyse the relationship between Setup Time Reduction and PLT.
4. To assess the relationship between Employee Involvement and PLT.
5. To evaluate the relationship between Layout Redesign and PLT.

2 LITERATURE REVIEW

2.1 Overview of Lean Manufacturing

Lean manufacturing is a management philosophy and operational strategy developed from the Toyota Production System (TPS), emphasising waste elimination, continuous improvement, and customer value creation (Womack & Jones, 2003). Globally, lean practices have been adopted to enhance productivity, quality and flexibility (Sim et al., 2024). However, despite its proven benefits in large-scale enterprises, SMEs often struggle to implement lean comprehensively because of financial constraints, fragmented systems, lack of trained personnel, and poor structural support (Gebeyehu, 2022). Nevertheless, lean manufacturing offers significant potential for SMEs to improve their production lead times, efficiency, and competitiveness (Bugvi et al., 2021; Samad et al., 2023).

2.2 Production Lead Time (Dependent Variable)

PLT refers to the total elapsed time required to convert raw materials into finished products, covering all processing, waiting, and movement stages. It is a key performance metric that reflects the responsiveness and efficiency of production systems for faster delivery, high customer satisfaction, and improved profitability.

Empirical studies have consistently demonstrated that the PLT is a significant indicator of operational performance. For instance, Al-Rifai (2024) found that reducing

PLT through lean implementation enhanced the order-fulfilment speed in electronic manufacturing. Similarly, Samad et al. (2023) showed that strategic layout redesign and setup-time reduction shortened PLT in the ready-made garment industry. However, these studies also highlight that the relationship between lean practices and PLT is not linear but contingent upon contextual factors, including process integration, workforce capability, and technological infrastructure.

2.3 Lean Manufacturing Practices (Independent Variables)

2.3.1 Value Stream Mapping (VSM)

VSM is a diagnostic tool used to visualise and analyse the flow of materials and information throughout a production process. It identifies bottlenecks, delays, and non-value-adding steps, allowing organisations to design an improved future-state process. According to Susilawati et al. (2021), VSM plays a pivotal role in identifying waste across operations, enabling managers to quantify the time losses that contribute to longer lead times.

In SMEs, VSM provides a strategic overview that facilitates decision-making for improvement initiatives, especially in complex production environments. Bugvi et al. (2021) reported a 21% reduction in lead time after integrating VSM with Setup Time Reduction and Layout Redesign in Pakistani SMEs, illustrating that VSM works best as part of an integrated system rather than a standalone method.

2.3.2 Just In Time (JIT)

JIT is a scheduling and production system designed to deliver materials and products at the precise time they are needed, thereby minimising inventory and work-in-progress. JIT focuses on synchronising production with customer demand and reducing waste associated with overproduction, waiting, and excessive storage (Sharma et al., 2021).

Although JIT has demonstrated success in large-scale manufacturing, its adoption by SMEs is often hampered by supply chain instability and inadequate coordination mechanisms. Dhawan (2023) emphasised that, in Indian SMEs, the absence of reliable

supplier networks limited JIT's potential to reduce PLT. Nevertheless, with close supplier collaboration and real-time information flow experience significant time savings and process agility are achieved.

2.3.3 Setup Time Reduction (STR)

STR focuses on minimising the time required to prepare machines, equipment, or processes for new production runs. It is often operationalised through the Single-Minute Exchange of Dies (SMED) technique, which standardises and simplifies setup procedures. By reducing the downtime between production runs, STR enhances flexibility and throughput (Ahmed et al., 2022).

Samad et al. (2023) demonstrated that STR implementation in Bangladesh's garment industry reduced average setup times by over 30%, resulting in faster delivery performance and increased equipment utilisation. Similarly, Lee, Park, and Kim (2023) integrated digital monitoring tools with SMED principles, achieving predictive maintenance and further reduction in idle time. STR is particularly critical for SMEs with high product variability because it allows quick adaptation to shifting customer demands.

2.3.4 Employee Involvement (EI)

EI refers to the degree of employee participation in decision-making, problem-solving, and continuous improvement activities. Within lean systems, employees are not merely task executors but key contributors to identifying waste and optimising processes. Research by Musa, Adebayo, & Gbolahan (2021) confirmed that empowering employees foster accountability and enhance the organisation's ability to detect inefficiencies early.

Similarly, Singh & Verma (2020) found that participative organisational cultures lead to higher motivation and faster problem resolution, ultimately improving operational performance. However, Gebeyehu (2022) cautioned that in many SMEs, hierarchical cultures and lack of training limit employee participation, undermining lean implementation. Effective EI thus requires supportive leadership, training programs, and a continuous improvement mindset aligned with organisational goals.

2.3.5 *Layout Redesign (LR)*

LR entails optimising the physical arrangement of equipment, workstations, and material flow within a production facility to minimise unnecessary movements and delays. Efficient plant layouts are essential for achieving a smooth process flow and reducing internal transportation waste. Kathem et al. (2023) demonstrated that layout redesign in Iraq's leather industry resulted in a 90% reduction in non-value-adding time, directly contributing to shorter PLT.

For SMEs, LR is often achieved impactfully at a relatively low cost compared to technological investments. Moreover, when combined with tools such as VSM and STR, LR provides a structural foundation for continuous flow and improved production and resource use.

2.3.6 *Relationship Between Lean Practices and Production Lead Time*

Lean tools are inherently designed to work synergistically, rather than in isolation. The integration of multiple practices yields exponential benefits, as each compensates for the limitations of other practices. VSM provides visibility into inefficiencies, JIT ensures timing precision, STR enhances flexibility, EI fosters continuous improvement, and LR optimises spatial efficiency.

Empirical evidence reinforces the interconnectedness of these tools. Bugvi et al. (2021) reported that the combined implementation of VSM, STR, and LR in manufacturing SMEs led to a 19% improvement in throughput and a 21% reduction in PLT. Similarly, Samad et al. (2023) found that STR and LR together yielded substantial operational gains by minimising downtime and streamlining material movement. In contrast, firms implementing isolated lean tools often fail to sustain results due to a lack of integration and employee ownership.

The relationship between lean practices and PLT thus supports a systemic perspective, where success arises from holistic adoption, cultural alignment, and strategic coordination across functions. This is supported by two complementary theories: Lean Thinking Theory (LTT) and Sociotechnical Systems Theory (SST).

2.3.7 *Lean Thinking Theory (LTT)*

Developed by Womack and Jones (2003), LTT identifies five guiding principles.

1. Define value from the customer's perspective.
2. The value stream was mapped to identify and eliminate waste.
3. Continuous flow is created by aligning the processes.
4. Establish pull systems to ensure just-in-time production.
5. Pursuing perfection through continuous improvement.

LTT forms the conceptual foundation for understanding how lean tools influence PLT. It posits that organisations can achieve superior operational performance by eliminating waste, optimising flow, and fostering a culture of continuous improvement. In this research, VSM, JIT, STR, EI, and LR are viewed as mechanisms through which the five lean principles are operationalised in SMEs.

2.3.8 *Sociotechnical Systems Theory (SST)*

SST, introduced by Trist and Bamforth (1951), emphasises the interdependence between an organisation's social and technical subsystems. The theory posits that optimal performance is achieved when both systems are jointly optimised. In the context of lean manufacturing, the technical subsystem includes processes, layouts, and equipment (e.g. JIT, STR, LR), whereas the social subsystem comprises human factors, such as employee involvement, leadership, and communication.

Rahman et al. (2023) argue that lean implementation failures often result from neglecting the human component of operations. Effective lean transformation, therefore, requires balancing process optimisation with workforce empowerment, a synergy directly reflected in this study's framework that integrates both technical (VSM, JIT, STR, LR) and social (EI) elements.

2.4 Hypothesis Development

Based on the reviewed literature and theoretical grounding, the following hypotheses are proposed:

- H₁: There is a relationship between Value Stream Mapping and Production Lead Time.
- H₂: There is a relationship between Just-In-Time and Production Lead Time.
- H₃: There is a relationship between Setup Time Reduction and Production Lead Time.
- H₄: There is a relationship between employee involvement and production lead-time.
- H₅: There is a relationship between Layout Redesign and Production Lead Time.

3 METHODOLOGY

3.1 Research Design

The study adopted a cross-sectional survey design in which data were collected once from respondents across multiple manufacturing SMEs. This approach aligns with previous lean manufacturing research that examines the relationships between organisational practices and performance outcomes (Setiawan et al., 2021; Kumar et al., 2023).

3.2 Population, Unit of Analysis and Sampling

The target population comprised employees of Malaysian SMEs within the manufacturing sector, as they possessed relevant first-hand experience. SMEs were defined according to the SME Corp Malaysia (2023) classification as organisations employing fewer than 200 full-time workers or having annual sales turnover below RM50 million. The unit of analysis were the employees, specifically production managers, supervisors, engineers, and quality control personnel involved in lean practices. These employees reflect organisational practices and perceptions, enabling inferential analysis at the firm level (Field, 2021).

A purposive sampling method was adopted to ensure that only respondents with relevant knowledge of lean manufacturing participated in the survey. The minimum sample size was determined using G*Power version 3.1.9.4, applying Cohen's (1988) parameters for multiple regression: medium effect size ($f^2 = 0.15$), significance level ($\alpha =$

0.05), power $(1-\beta) = 0.80$, and five predictors. The analysis indicated that at least 92 participants were required. To enhance statistical robustness, 103 valid responses were collected, meeting the adequacy criterion recommended by Hair et al. (2019) for multivariate research (15–20 observations per variable).

3.3 Instrument Development

The research instrument was a structured questionnaire consisting of 42 items categorised according to the study variables. The items were adapted from previously validated instruments used in lean manufacturing and operations management studies (Alsulami & Alzahrani, 2022; Kumar et al., 2023; Ghosh & Das, 2024).

3.4 Validity, Reliability and Pilot Study

To ensure validity, the questionnaire was reviewed by academic experts in lean manufacturing and industry practitioners. Their feedback helped refine the wording, clarity, and contextual relevance. Subsequently, Exploratory Factor Analysis (EFA) was conducted on pilot data to assess construct validity. The Kaiser-Meyer-Olkin (KMO) value of 0.763 exceeded the 0.60 threshold (Kaiser, 1974), and Bartlett's Test of Sphericity was significant ($\chi^2 = 128.499$, $p < 0.001$), confirming data suitability for factor analysis. A pilot study involving 31 respondents test yielded Cronbach's alpha coefficient of 0.933, exceeding Nunnally and Bernstein's (1994) recommended threshold of 0.70. This indicates high reliability without redundancy among the items. Table 1 summarises the results. The strong reliability result validated the instrument's suitability for data collection and statistical analysis.

Table 1

Reliability Coefficient (Pilot Study)

| Construct | No. of Items | Cronbach's Alpha | Reliability Level |
|-------------------------|--------------|------------------|-------------------|
| All Constructs Combined | 42 | 0.933 | Excellent |

3.5 Data Analysis Techniques

The data analysis followed a structured multistep process:

1. Descriptive Analysis: Summarised demographic variables (age, gender, position, experience, and years of lean practice).
2. Reliability Analysis: Cronbach's alpha confirmed internal consistency.
3. Factor Analysis: Assessed construct validity and identified inter-item correlations.
4. Correlation Analysis: Pearson's r measured the linear relationships between lean practices and PLT.
5. Multiple Regression Analysis: Determined the individual and collective influence of lean tools on PLT.

Assumptions of normality, linearity, multicollinearity, and homoscedasticity were tested to ensure model validity. Variance Inflation Factor (VIF) values were below 5, indicating no multicollinearity issues.

3.6 Ethical Considerations

Ethical standards set by the Faculty of Business and Communication, INTI International University, were upheld throughout the research process. Participation was voluntary and respondents were given full information regarding the purpose and confidentiality of the study. After submitting responses, the participants provided informed consent. No financial incentives were offered to ensure unbiased participation. The data were stored securely and used solely for academic analysis.

4 RESULTS / FINDINGS

4.1 Respondent Demographics

A total of 103 valid responses were obtained from managers, engineers, and production supervisors of Malaysian manufacturing SMEs. Table 2 summarises the demographic profile.

Table 2*Demographic Characteristics of Respondents*

| Variable | Category | Frequency | Percentage (%) |
|--------------------|-------------------|-----------|----------------|
| Gender | Male | 63 | 61.2 |
| | Female | 40 | 38.8 |
| Age | 21–30 years | 24 | 23.3 |
| | 31–40 years | 39 | 37.9 |
| | 41–50 years | 30 | 29.1 |
| | Above 50 years | 10 | 9.7 |
| Education | Diploma | 26 | 25.2 |
| | Bachelor's Degree | 56 | 54.4 |
| | Master's Degree | 21 | 20.4 |
| Working Experience | Below 5 years | 27 | 26.2 |
| | 5–10 years | 45 | 43.7 |
| | Above 10 years | 31 | 30.1 |
| Position | Supervisor | 37 | 35.9 |
| | Engineer | 42 | 40.8 |
| | Manager | 24 | 23.3 |

The demographic data indicated that many respondents were male (61.2%), aged between 31 and 40 years (37.9%), and had between 5 and 10 years of experience in manufacturing. More than half (54.4%) had a bachelor's degree, reflecting a moderately well-educated workforce familiar with lean manufacturing concepts.

4.2 Correlation Analysis

The Pearson Correlation Coefficient (r) was used to examine the strength and direction of relationships between the independent variables (VSM, JIT, STR, EI, and LR) and the dependent variable (PLT). Table 3 presents the correlation matrix.

Table 3*Correlation Matrix*

| Variables | PLT | VSM | JIT | STR | EI | LR |
|-----------|---------|---------|---------|---------|---------|----|
| PLT | 1 | | | | | |
| VSM | 0.514** | 1 | | | | |
| JIT | 0.622** | 0.531** | 1 | | | |
| STR | 0.673** | 0.480** | 0.562** | 1 | | |
| EI | 0.457** | 0.492** | 0.507** | 0.498** | 1 | |
| LR | 0.658** | 0.471** | 0.589** | 0.628** | 0.532** | 1 |

Note: Correlation is significant at the 0.01 level (2-tailed)

The correlation results indicate that all lean manufacturing practices are positively and significantly correlated with production lead-time. The strongest correlations were

observed between STR and PLT ($r = 0.673$, $p < 0.01$) and between LR and PLT ($r = 0.658$, $p < 0.01$), suggesting that setup optimisation and layout improvement have substantial effects on reducing PLT. Meanwhile, JIT also showed a strong correlation with PLT ($r = 0.622$, $p < 0.01$), followed by VSM ($r = 0.514$, $p < 0.01$), and EI ($r = 0.457$, $p < 0.01$). These results support all five hypotheses (H1–H5).

4.3 Multiple Regression Analysis

To identify the combined and individual effects of lean practices on PLT, a multiple regression analysis was performed. The results are summarised in Table 4.

Table 4

Regression Coefficients and Model Summary

| Predictor | Unstandardized Coefficient (β) | Std. Error | Standardised Coefficient (β) | t-value | Sig. (p) |
|------------|--|------------|--------------------------------------|---------|----------|
| (Constant) | 0.742 | 0.174 | – | 4.261 | 0.000 |
| VSM | 0.084 | 0.063 | 0.071 | 1.332 | 0.186 |
| JIT | 0.201 | 0.073 | 0.188 | 2.759 | 0.007** |
| STR | 0.321 | 0.061 | 0.307 | 5.246 | 0.000** |
| EI | 0.076 | 0.067 | 0.068 | 1.134 | 0.260 |
| LR | 0.282 | 0.058 | 0.267 | 4.879 | 0.000** |

Model Summary:

- $R^2 = 0.716$
- Adjusted $R^2 = 0.704$
- $F(5, 97) = 48.71$, $p < 0.001$

Note: $p < 0.05$ = significant; $p < 0.01$ = highly significant

The model explains 71.6% of the variance in PLT, indicating that the combination of the five lean practices significantly affects PLT. The F-statistic (48.71, $p < 0.001$) confirmed that the regression model was statistically significant. Among the predictors, STR had the largest standardised coefficient ($\beta = 0.307$, $p < 0.001$), followed by LR ($\beta = 0.267$, $p < 0.001$) and JIT ($\beta = 0.188$, $p = 0.007$). These three variables were statistically significant predictors of reduced PLT. In contrast, VSM ($p = 0.186$) and EI ($p = 0.260$) were not significant predictors in the model, suggesting that their influence on PLT is indirect or mediated through other practices.

4.4 Hypothesis Testing Summary

Based on the correlation and regression results, the hypotheses were evaluated, as shown in Table 5.

Table 5

Hypothesis Testing Results

| Hypothesis | Statement | Result |
|----------------|--|---------------|
| H ₁ | There is a significant relationship between Value Stream Mapping and Production Lead Time. | Not Supported |
| H ₂ | There is a significant relationship between Just-In-Time and Production Lead Time. | Supported |
| H ₃ | There is a significant relationship between Setup Time Reduction and Production Lead Time. | Supported |
| H ₄ | There is a significant relationship between Employee Involvement and Production Lead Time. | Not Supported |
| H ₅ | There is a significant relationship between Layout Redesign and Production Lead Time. | Supported |

The results indicate that three lean practices—JIT, STR, and LR—significantly influence PLT, whereas VSM and EI do not. This finding highlights the greater effectiveness of operational and technical practices compared to cultural or diagnostic tools in reducing lead time among Malaysian SMEs.

4.5 Summary of Findings

The quantitative findings revealed the following.

1. STR is the most influential factor, demonstrating that process standardisation and machine readiness directly improve time efficiency.
2. LR substantially contributes to reducing internal material movement and bottlenecks, further improving PLT.
3. JIT enhances production synchronisation and reduces waiting time across processes.
4. VSM, although conceptually vital for identifying inefficiencies, does not significantly influence PLT unless integrated with other lean practices.
5. EI shows a limited direct effect on PLT, possibly because its outcomes manifest indirectly through a culture of continuous improvement rather than immediate operational gains.

Collectively, the findings confirm that lean manufacturing practices significantly enhance production efficiency, with the technical aspects STR, JIT, and LR having the strongest impact on PLT in Malaysian SMEs.

5 DISCUSSIONS OF KEY FINDINGS

Overall, the results demonstrate that while lean practices collectively improve production efficiency, the significance of individual tools varies according to their operational and organisational contexts. Specifically, JIT, STR, and LR significantly reduced PLT, whereas VSM and EI did not show direct statistical significance.

5.1 Influence of JIT on PLT

The study found that JIT had a significant positive influence on PLT ($\beta = 0.188$, $p < 0.01$), supporting Hypothesis 2 (H₂). This finding is consistent with Sharma et al. (2021), who reported that JIT systems streamline material flow, reduce inventory holding time, and synchronise production with demand fluctuations. In Malaysian SMEs, where resource optimisation is crucial, implementing JIT allows firms to reduce buffer stock and rework time, thereby enhancing overall responsiveness.

The effectiveness of JIT highlights its adaptability to smaller production scales when supported by reliable supplier coordination and efficient scheduling. According to Rahman et al. (2023), JIT's impact of JIT is contingent on supplier integration, as any supply chain disruption can reverse its benefits. Therefore, this study reinforces that SMEs adopting JIT must focus on developing stable supplier relationships, real-time data systems, and cross-functional communication to sustain reduced lead-times.

5.2 Influence of STR on PLT

Setup Time Reduction (STR) emerged as the most influential variable affecting PLT ($\beta = 0.307$, $p < 0.001$), confirming Hypothesis 3 (H₃). This aligns with Ahmed et al. (2022) and Samad et al. (2023), who demonstrated that minimising setup time through SMED principles leads to shorter downtime, improved equipment utilisation, and increased throughput.

For SMEs, where production flexibility and quick turnaround are critical, the STR directly supports lean objectives by allowing rapid adjustments between production runs. The findings validate LTT's third principle, "create continuous flow", as the STR reduces interruptions and facilitates smoother transitions between batches.

In the context of Malaysian SMEs, the prominence of the STR suggests that tangible process-oriented improvements yield greater benefits than abstract strategic planning tools. Many SMEs operate in job-shop environments with frequent product changeovers; thus, streamlining setups directly translates into measurable reductions in PLT and overall operational efficiency.

5.3 Influence of LR on PLT

Layout Redesign (LR) was also found to be significantly and positively related to PLT ($\beta = 0.267$, $p < 0.001$), supporting Hypothesis 5 (H_5). This finding aligns with Kathem et al. (2023), who showed that optimising spatial arrangements minimises unnecessary motion, handling, and transport time. LR supports LTT's fourth principle, "establish flow and pull"—by physically restructuring production lines to improve workflow continuity.

Unlike automation, which requires substantial investment, LR can be implemented using existing resources through process mapping and reorganisation. Bugvi et al. (2021) also reported that integrating LR with STR and JIT amplified performance gains, suggesting that physical reconfiguration should complement procedural changes.

The combined impact of STR and LR accounted for a major portion of the explained variance in PLT ($R^2 = 0.716$), emphasising that technical process improvements are central to operational excellence in SMEs.

5.4 Influence of VSM on PLT

Although VSM was positively correlated with PLT ($r = 0.514$), it was not a statistically significant predictor in the regression model ($p = 0.186$), leading to the rejection of Hypothesis 1 (H_1). This finding aligns with previous studies (Reda & Dvivedi, 2022) that highlight VSM's diagnostic rather than operational nature of VSM.

VSM helps identify inefficiencies and visualise process flows, but it does not directly reduce PLT unless it is followed by actionable process changes. In many SMEs, VSM exercises are often conducted superficially, often as part of training or certification initiatives, without the full implementation of recommended improvements. This may explain the limited statistical impact on PLT in this study.

From the SST perspective, VSM is a technical tool that requires social engagement (employee and managerial follow-through) to generate results. The lack of a direct impact in this study implies that Malaysian SMEs may use VSM as a planning tool rather than an ongoing improvement mechanism, highlighting the need for sustained commitment beyond mapping exercises.

5.5 Influence of EI on PLT

EI was found to have a positive but insignificant relationship with PLT ($p = 0.260$), thus rejecting Hypothesis 4 (H_4). While the literature strongly supports EI as a driver of continuous improvement (Singh & Verma, 2020; Gebeyehu, 2022), its impact may not immediately manifest in measurable time reductions. Instead, EI contributes indirectly through enhanced morale, ownership, and problem-solving capability factors that influence long-term performance rather than short-term lead times.

Mrope & Namusonge (2022) noted that many SMEs adopt lean tools without developing a supportive culture that encourages feedback and idea generation from frontline workers. Hence, the importance of integrating human-centric initiatives, such as training, leadership development, and communication systems, into lean technical programs to achieve sustained improvements in PLT.

From an SST perspective, EI represents the “social” subsystem that must complement technical lean tools. Without adequate synchronisation, the social dimension remains underleveraged, explaining the absence of direct statistical significance in this study.

5.6 Managerial Implications

The study’s findings have several practical implications for SME managers, consultants, and policymakers.

1. **Prioritise Technical Process Improvements:** SMEs should focus on STR and LR as primary interventions, as they deliver the most immediate and measurable reductions in PLT.
2. **Enhance Supplier Collaboration:** Effective JIT implementation requires stable supplier relationships and real-time communication to avoid disruptions.
3. **Institutionalise Value Stream Mapping:** Managers should integrate VSM as a continuous diagnostic tool rather than as a one-time activity.
4. **Develop Lean Culture and Workforce Capability:** Although EI was not statistically significant, its indirect benefits on innovation and problem solving should not be underestimated. Training and participative management practices can enhance long-term operational resilience.
5. **Adopt an Integrated Lean Strategy:** The success of lean implementation depends on system-wide alignment. Policymakers should support SMEs through financial incentives, training programs, and collaborative platforms to strengthen their technical and human capacities.

5.7 Comparison with Previous Studies

The results are largely consistent with those of prior studies in both developed and developing economies. For example:

1. **STR and LR:** The current findings echo those of Samad et al. (2023) and Kathem et al. (2023), who identified these factors as key determinants of efficiency in resource-constrained manufacturing environments.
2. **JIT:** The results align with Sharma et al. (2021) and Dhawan (2023), confirming that synchronised scheduling and reduced inventory contribute to a lower PLT.
3. **EI:** The absence of direct significance supports Gebeyehu (2022), who found that employee participation influences long-term improvement outcomes rather than short-term metrics.
4. **VSM:** The limited effect of VSM corresponds with Reda & Dvivedi (2022), who emphasised that mapping alone does not produce improvement without follow-through actions.

Thus, this study reinforces the emerging consensus that lean success in SMEs depends on contextual adaptation and cross-functional integration rather than the uniform adoption of tools.

6 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study examined the influence of five lean manufacturing practices—VSM, JIT, STR, EI, and LR—on sustainable PLT among Malaysian SMEs guided by LTT and SST. Using a quantitative approach with SPSS analysis, the findings revealed that STR, LR, and JIT significantly and positively affected PLT, demonstrating that streamlined setups, efficient layouts, and synchronised production enhanced time efficiency and responsiveness. STR was the strongest predictor, highlighting the importance of flexible, standardised setups. In contrast, VSM and EI showed no significant impact, suggesting that their effects depend on implementation maturity and cultural support. Holistic lean adoption integrating technical and human elements can improve operational performance, reduce lead time, and strengthen competitiveness in Malaysian SMEs.

6.2 Recommendations

Based on the research outcomes, the following recommendations are proposed for SME managers, policymakers, and researchers:

1. **Prioritise STR and LR:** SMEs should initially focus on process simplification and efficient factory layout. These practices offer high impact with relatively low investment and directly reduce PLT by minimising downtime and material handling.
2. **Strengthening Supplier and Information Integration for JIT:** Effective JIT implementation requires stable supplier relationships, real-time communication systems, and accurate demand forecasting. Managers should invest in digital tools (e.g. ERP or IoT-based scheduling) to support synchronised operations.
3. **Institutionalise Continuous Improvement Through VSM:** Rather than treating VSM as a one-time exercise, SMEs should establish periodic value-stream audits

to identify waste and track improvement progress. Linking VSM outcomes to strategic KPIs ensures accountability and measurable impact.

4. **Empower Employees through Structured Involvement Programs:** Although EI was not statistically significant in this study, it remains vital for sustaining long-term lean success. SMEs should foster a participative culture through training, suggestion systems, and recognition schemes to encourage bottom-up innovation.
5. **Adopt an Integrated Lean Implementation Strategy:** Successful lean transformation requires coordination across all functions. SME leaders should align lean initiatives with organisational strategy, performance metrics, and customer expectations to ensure sustained outcomes.
6. **Enhance Government and Institutional Support:** Policymakers can facilitate lean SME adoption by providing training grants, technical assistance, and collaborative networks with research institutions. Public-private partnerships can accelerate lean diffusion among smaller firms.

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Authors' Contribution

All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

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