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WHICH LEAN PRACTICES DRIVE OPERATIONAL PERFORMANCE? A CONCEPTUAL FRAMEWORK FOR THE MALAYSIAN ELECTRICAL AND ELECTRONICS INDUSTRY

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Abstract:

This paper develops a conceptual framework examining how six Lean Manufacturing Practices (LMPs) influence Operational Performance (OP) in the Malaysian Electrical and Electronics (E&E) industry. OP is conceptualized through cycle time, defect rate, on-time delivery, and cost efficiency. Although lean manufacturing is widely recognized as a driver of operational excellence, empirical evidence from emerging-economy manufacturing contexts remains inconsistent, suggesting that individual lean practices may not contribute equally across industrial settings. Drawing on the Resource-Based View (RBV) and the Toyota Production System (TPS), the paper proposes that Cellular Manufacturing, Pull System, Continuous Improvement, Total Quality Management, Total Productive Maintenance, and Small Lot Production exert differential influences on OP in a mature, capital-intensive industry. The Malaysian E&E context is theoretically distinctive because it combines long-standing multinational lean adoption, stringent international quality requirements, short product life cycles, and high capital intensity. Six propositions are developed to guide future empirical research. The paper contributes to lean scholarship by conceptualizing lean implementation as a portfolio of practices rather

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than a uniformly beneficial bundle, and by offering a context-specific framework aligned with Malaysia's National Industrial Master Plan 2030 and National Semiconductor Strategy.

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Keywords:

Lean Manufacturing Practices, Operational Performance, Conceptual Framework, Resource-Based View, Toyota Production System, Electrical and Electronics Industry, Malaysia

Introduction

The Electrical and Electronics (E&E) industry remains a cornerstone of Malaysia's manufacturing sector and a major contributor to national export earnings, foreign direct investment, and high-skilled employment (Ministry of Investment, Trade and Industry, 2023). Since the establishment of Malaysia's first semiconductor plant in Penang in 1972, the country has developed into one of the world's leading exporters of integrated circuits, with particular strength in assembly, testing, and packaging operations. The Northern Corridor Economic Region (NCER), comprising Penang, Kedah, and Perak, serves as a central hub for high-technology manufacturing and hosts a substantial share of the sector's operational activities. Over the past five decades, this regional ecosystem has developed the human capital, supplier networks, and infrastructure required to sustain Malaysia's attractiveness as an E&E investment destination.

Despite this strategic importance, Malaysian E&E firms operate in a volatile global environment shaped by geopolitical tensions, supply chain restructuring under the China Plus One strategy, and continuous pressure to improve cycle time, defect rate, on-time delivery, and cost efficiency (Bank Negara Malaysia, 2015; Khan et al., 2025). The recent growth of foreign direct investment in the NCER has also intensified pressure on local capacity, supplier ecosystems, and managerial capability. In this environment, firms are expected to perform simultaneously across multiple operational dimensions: shorter lead times, lower defect rates, reliable delivery, and tighter cost control. A common managerial response has been the systematic adoption of Lean Manufacturing Practices (LMPs), which aligns with national industrial priorities under the National Industrial Master Plan 2030 and the National Semiconductor Strategy (Collaborative Research in Engineering, Science and Technology [CREST], 2024; Ministry of Investment, Trade and Industry, 2023).

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However, empirical studies on whether and how LMPs improve operational performance (OP) in emerging-economy manufacturing environments remain inconsistent (Elemure et al., 2023; Panigrahi et al., 2024). Some studies report strong performance gains from comprehensive lean implementation, whereas others find weak or context-dependent effects. This inconsistency creates a theoretical dilemma for the conventional view of lean as a uniformly beneficial bundle of practices. Classical lean literature often treats lean tools as generally valuable across contexts, but more recent contingency-oriented research suggests that their effects depend on industry characteristics, technological maturity, and organizational capability (Bortolotti et al., 2015; Tortorella et al., 2024).

This dilemma is particularly relevant in mature, capital-intensive industries such as Malaysia's E&E industry. In this setting, multinational corporations have implemented lean systems for decades, international quality standards have made several lean routines baseline requirements, and the marginal contribution of each practice depends on its alignment with the industry's technological and operational logic. A more nuanced theoretical perspective is therefore required. Such a perspective should disaggregate lean into its constituent practices and explain how each practice contributes differently to OP within a mature manufacturing context.

Against this background, this paper develops a conceptual framework that links six LMP dimensions to OP in the Malaysian E&E industry. The framework is grounded in two complementary theoretical perspectives: the Resource-Based View (RBV) (Barney, 1991) and the Toyota Production System (TPS) (Ohno, 1988; Womack & Jones, 1996). Six propositions are formulated to guide future empirical research. The paper makes three contributions. First, it extends classical lean theory by specifying boundary conditions for individual lean practices in a mature, capital-intensive setting. Second, it applies RBV by treating each lean practice as a distinct organizational resource whose contribution depends on rarity, inimitability, and contextual fit. Third, it provides a Malaysian-specific framework that connects lean research with the strategic priorities of the National Industrial Master Plan 2030 and the National Semiconductor Strategy.

Literature Review

Operational Performance

Operational performance refers to the measurable effectiveness of an internal production system in delivering products that meet customer requirements at competitive cost (Panigrahi et al., 2024; Purbowo et al., 2022). In manufacturing contexts, OP is commonly assessed through four interdependent dimensions: cycle time, defect rate, on-time delivery, and cost efficiency (Fahmy-Abdullah et al., 2019; Teoh & Abu, 2018). Cycle time reflects the speed and efficiency of production processes, defect rate captures the quality of output, on-time delivery indicates reliability in fulfilling customer commitments, and cost efficiency reflects the ability to convert inputs into outputs without unnecessary resource consumption. In the E&E sector, where product life cycles are short, customer technical requirements are stringent, and capital investment is high, simultaneous improvement across these four dimensions is essential for competitiveness (Bank Negara Malaysia, 2015; Handoyo et al., 2023).

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Lean Manufacturing Practices

Lean manufacturing, originating from the Toyota Production System, seeks to eliminate waste, stabilize processes, and create continuous flow through coordinated practices (Ohno, 1988; Womack & Jones, 1996). Shah and Ward (2007) define lean production as an integrated socio-technical system aimed at reducing waste while improving supplier, customer, and internal processes. This article focuses on six commonly discussed LMP dimensions: Cellular Manufacturing, Pull System, Continuous Improvement, Total Quality Management, Total Productive Maintenance, and Small Lot Production. Although these practices are often treated as a collective lean bundle, their relative influence on performance may vary according to industrial context, technological maturity, and managerial capability (Bortolotti et al., 2015; Tortorella et al., 2024).

Resource-Based View as Theoretical Lens

The Resource-Based View (RBV) provides an integrative theoretical lens for this framework. According to RBV, firms obtain sustainable competitive advantage when they possess and deploy resources that are valuable, rare, inimitable, and non-substitutable (Barney, 1991). From this perspective, each lean practice can be understood as an organizational resource whose performance contribution depends not only on adoption, but also on the extent to which the practice is difficult to imitate within the host industry. In mature industries where some lean practices are widely adopted, those practices may become baseline expectations rather than sources of differentiation. Conversely, practices that require firm-specific investment in layout design, equipment reliability, workforce discipline, and changeover capability may continue to create performance differences among firms. This logic is highly relevant to Malaysia's E&E industry, where multinational firms, international quality systems, and long-standing lean exposure have shaped the maturity of lean implementation.

Lean Manufacturing in Emerging-Economy Contexts

Recent empirical studies on lean implementation in emerging economies show that performance outcomes vary considerably. Research in Malaysia, Indonesia, and India indicates that the effect of lean adoption depends on firm size, ownership structure, supply chain position, technological capability, and the maturity of the quality system (Goenaga, 2024; Osman et al., 2020; Panigrahi et al., 2024; Purbowo et al., 2022). In mature manufacturing environments where basic lean adoption is already widespread, practices that are generally considered beneficial may generate only weak or moderate marginal effects (Tortorella et al., 2024).

These findings motivate a more disaggregated theoretical treatment of lean. Rather than asking only whether lean improves performance, researchers increasingly ask which lean practices improve which aspects of performance, and under which conditions (Bortolotti et al., 2015; Elemure et al., 2023). The framework developed in this article reflects this shift by conceptualizing LMPs as a portfolio of distinct practices whose individual contributions depend on the structural characteristics of the host industry. Malaysia's E&E industry, with its concentration of multinational firms, long history of lean implementation, and stringent international quality requirements, provides a suitable context for examining these differential contributions.

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Proposed Conceptual Framework

This section presents the conceptual framework and formulates six propositions. OP is treated as the dependent variable and is operationalized through cycle time, defect rate, on-time delivery, and cost efficiency. The six LMP dimensions are treated as independent variables. Figure 1 illustrates the proposed relationships.

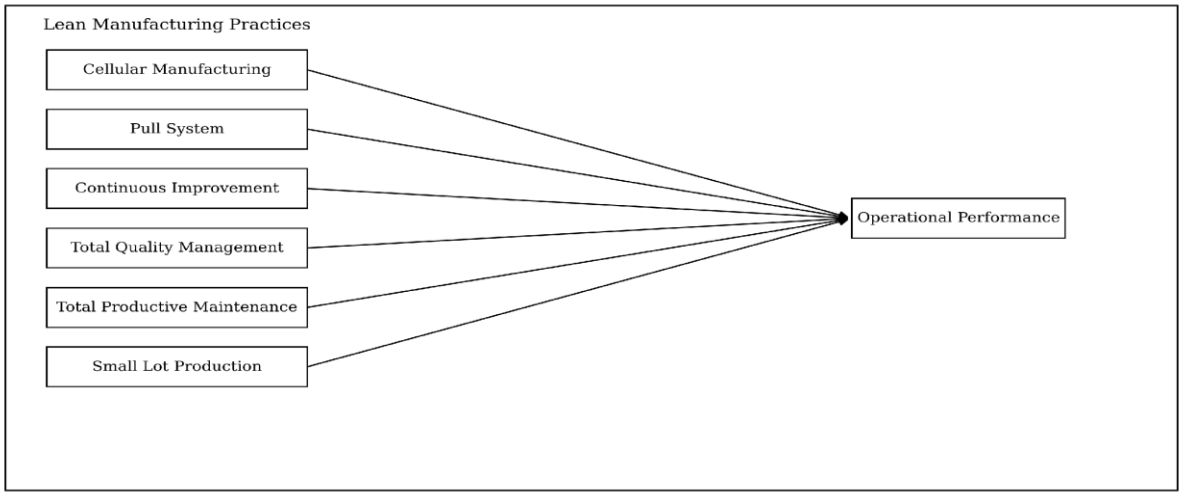

Figure 1: Conceptual Framework

Cellular Manufacturing and Operational Performance

Cellular manufacturing reorganizes production layouts by grouping machines and operators according to product families, thereby reducing material movement, waiting time, and changeover time (Shafer & Charnes, 1993). In the Malaysian E&E industry, where product variety and switching frequency are high, cell-based layouts can improve responsiveness through faster product transitions, flexible operator deployment, and stronger visual control. Cellular configurations may also enhance coordination in semiconductor back-end operations, where assembly, testing, and packaging processes must be carefully synchronized.

> **Proposition 1 (P1):** Cellular Manufacturing is positively related to Operational Performance in the Malaysian E&E industry.

Pull System and Operational Performance

Pull system practices link production to downstream demand signals and limit work-in-process through mechanisms such as kanban and just-in-time replenishment (Sugimori et al., 1977). By reducing buffer inventory, pull systems expose process abnormalities and encourage timely problem solving. In tightly integrated and highly automated E&E supply chains, pull practices remain theoretically important because they influence inventory carrying costs, throughput time, and the visibility of production problems.

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From an RBV perspective, the value of pull system practices in mature manufacturing depends on a firm's discipline in maintaining authorized work-in-process levels and on the responsiveness of its upstream suppliers. These capabilities are firm-specific and may be difficult to replicate consistently.

> **Proposition 2 (P2):** Pull System practices are positively related to Operational Performance in the Malaysian E&E industry.

Continuous Improvement and Operational Performance

Continuous Improvement institutionalizes incremental problem solving at the shop-floor level. Its effectiveness depends on organizational absorptive capacity and the empowerment of frontline employees (Bessant et al., 2001; Imai, 1986). Continuous Improvement supports OP by enabling the cumulative refinement of work procedures, systematic identification of waste, and diffusion of best practices across the organization. From an RBV perspective, although Continuous Improvement is widely recognized as a managerial principle, the cultural and behavioral capabilities required to sustain it remain firm-specific and difficult to imitate.

> **Proposition 3 (P3):** Continuous Improvement is positively related to Operational Performance in the Malaysian E&E industry.

Total Quality Management and Operational Performance

Total Quality Management (TQM) has been linked to improved defect rates and customer satisfaction across diverse manufacturing contexts, although the magnitude of its contribution varies with the maturity of quality systems already in place (Dean & Bowen, 1994; Nair, 2006). TQM supports OP through statistical process control, supplier quality management, customer-focused design, and quality awareness throughout the workforce. In the Malaysian E&E industry, where standards such as ISO 9001 and IATF 16949 are core requirements, TQM is expected to support performance through disciplined quality routines. However, because TQM is widely adopted, its differentiating power may be weaker than that of more firm-specific practices.

> **Proposition 4 (P4):** Total Quality Management is positively related to Operational Performance in the Malaysian E&E industry.

Total Productive Maintenance and Operational Performance

Total Productive Maintenance (TPM) aims to achieve high equipment reliability by sharing maintenance responsibilities between operators and maintenance specialists (Nakajima, 1988). TPM is particularly relevant in capital-intensive sectors such as semiconductors, where unplanned downtime creates significant financial losses and directly affects throughput. TPM supports OP by extending equipment life, reducing process variability, and minimizing disruptions caused by breakdowns. From an RBV perspective, TPM represents a valuable resource because its effectiveness depends on cumulative investment in equipment monitoring, operator training, maintenance discipline, and data-driven reliability routines.

> **Proposition 5 (P5):** Total Productive Maintenance is positively related to Operational Performance in the Malaysian E&E industry.

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Small Lot Production and Operational Performance

Small Lot Production Complements Cellular Manufacturing and Pull System practices by enabling firms to respond quickly to short product life cycles in the E&E industry (Schonberger, 1982). By reducing batch sizes, it shortens throughput time, lowers inventory carrying costs, accelerates defect detection, and improves manufacturing flexibility. In an industry where product mix can change rapidly across short order horizons, this flexibility represents a significant operational advantage. From an RBV perspective, Small Lot Production requires investment in setup reduction, changeover capability, and workforce coordination, which are firm-specific and time-consuming to develop.

> **Proposition 6 (P6):** Small Lot Production is positively related to Operational Performance in the Malaysian E&E industry.

Summary of Propositions

Table 1 summarizes the six propositions of the proposed framework.

Table 1: Summary of Conceptual Propositions

Proposition	Conceptual Relationship	Theoretical Basis
P1	Cellular Manufacturing to Operational Performance	RBV / TPS
P2	Pull System to Operational Performance	RBV / TPS
P3	Continuous Improvement to Operational Performance	RBV / TPS
P4	Total Quality Management to Operational Performance	RBV / TPS
P5	Total Productive Maintenance to Operational Performance	RBV / TPS
P6	Small Lot Production to Operational Performance	RBV / TPS

Source: Authors' own compilation. Note: RBV = Resource-Based View; TPS = Toyota Production System.

Discussion

Theoretical Implications

The proposed framework makes three theoretical contributions to the lean manufacturing literature. First, it extends classical TPS thinking by articulating boundary conditions for individual lean practices in a mature, capital-intensive context. Classical TPS literature has often treated lean practices as a coherent and generally beneficial bundle, with limited attention

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to the conditions under which individual practices contribute differently to OP. The proposed framework recognizes that lean practices vary in their structural logic. Cellular Manufacturing, TPM, and Small Lot Production operate through physical, equipment-centered, and capability-intensive mechanisms, whereas Pull System, Continuous Improvement, and TQM operate more strongly through procedural and behavioral mechanisms. This distinction helps explain why empirical studies report heterogeneous lean-performance effects across industrial contexts (Bortolotti et al., 2015; Tortorella et al., 2024).

Second, the framework integrates RBV into lean manufacturing research in a more disaggregated manner. Rather than treating lean as a single firm-level resource, it treats each of the six practices as a distinct organizational resource whose performance value depends on rarity, inimitability, and contextual fit. This perspective provides a theoretical explanation for why the effects of lean implementation may vary across industries with different levels of lean diffusion and technological maturity.

Third, by grounding the framework in the Malaysian E&E context, this paper contributes a context-specific perspective that connects global lean theory with the empirical realities of a mature manufacturing industry. The Malaysian E&E industry is theoretically distinctive because it combines high capital intensity, stringent international quality requirements, short product life cycles, and a dense concentration of firms. These conditions intensify the differential effects of individual lean practices on operational outcomes and provide a basis for future empirical studies in Malaysia and comparable Asian manufacturing settings.

Practical Implications

For E&E operations managers, the framework suggests a more selective and theory-informed approach to lean investment. Priority should be given to practices with strong theoretical relevance in capital-intensive settings, particularly TPM, Cellular Manufacturing, and Small Lot Production, because these practices rely on firm-specific resources that are difficult for competitors to imitate. Investments in Pull System, Continuous Improvement, and TQM should remain important for maintaining operational stability, but firms should be cautious about expecting these practices alone to create strong performance differentiation when they are already widely institutionalized. The framework also provides a basis for diagnostic review. Firms with inconsistent operational results despite substantial lean investments may benefit from reassessing whether their lean portfolios are concentrated in practices that have lost differentiating power, or whether they sufficiently support practices that are more likely to influence performance in their specific industry context.

Policy Implications

For policymakers driving the National Industrial Master Plan 2030 and the National Semiconductor Strategy, the framework highlights the need for targeted investment in lean practices that sustain differentiation in mature manufacturing industries (CREST, 2024; Ministry of Investment, Trade and Industry, 2023). Given the importance of equipment availability to E&E competitiveness, policy support should encourage equipment reliability infrastructure, predictive maintenance technologies, condition-monitoring systems, and Industry 4.0-enabled TPM (Othman et al., 2022). Subsidies, tax incentives, and matching grants could be aligned with investments that strengthen equipment reliability, manufacturing flexibility, and small-lot production capability. Conversely, generic lean training programs that

promote uniform adoption of all lean practices may produce diminishing returns. National training institutions, trade associations, universities, and agencies such as the Malaysian Investment Development Authority and Malaysia Productivity Corporation can support managers in diagnosing which lean practices are most likely to create competitive advantage under specific organizational and industry conditions.

Conclusion

This paper proposed a conceptual framework linking six LMP dimensions to OP, comprising cycle time, defect rate, on-time delivery, and cost efficiency, within the Malaysian E&E industry. Grounded in RBV and TPS, the framework reconceptualizes lean implementation as a portfolio of structural resources whose individual contributions vary according to the technological maturity and capital intensity of the host industry. Six propositions were developed to guide future empirical inquiry. The framework establishes boundary conditions for individual lean practices, integrates a disaggregated RBV perspective into the lean discourse, and offers a context-specific framework relevant to Malaysia's industrial policy priorities. For operations managers and policymakers, it provides a theoretically grounded basis for designing lean investment strategies that are calibrated to the structural characteristics of mature manufacturing industries.

Several avenues for future empirical inquiry emerge. First, the six propositions should be tested using quantitative survey research, with Partial Least Squares Structural Equation Modeling (PLS-SEM) as an appropriate analytical technique because of the model's complexity and the need to estimate differential effects. The Malaysian E&E industry, with its dense concentration of firms in the NCER, provides a suitable empirical setting. Second, longitudinal designs could clarify the temporal dynamics of lean implementation effects. Third, the framework could be extended by incorporating Industry 4.0 technologies as an additional contingency. Fourth, comparative studies across Asian manufacturing economies could test the generalizability of the framework beyond Malaysia. Fifth, qualitative case studies could complement quantitative testing by revealing the micro-level mechanisms through which specific lean practices interact with industry-specific conditions on the shop floor.

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