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CRITERIA FOR LEAN MATURITY ASSESSMENT OF AN ORGANIZATION AT THE OPERATIONAL LEVEL

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ABSTRACT

This study methodically compiles and analyzes the current paradigms to develop an operational-level lean maturity framework. The study effectively creates a multidimensional lean maturity evaluation framework with six primary criteria and 57 operational-specific indicators. Each major criterion is categorized based on four degrees of lean maturity: level 1-understanding, level 2-implementation, level 3-improvement, and level 4-sustainability, which is fundamental to suggest a road map for creating a lean culture of continuous improvement for enterprises. In-depth interviews with 5 experts are used to refine the framework, followed by empirical validation through pilot deployments at two typical electrical and electronics companies, X and Y. The pilot results indicate that both X and Y are currently at level 3-improvement. Ultimately, this framework provides organizations with a strategic roadmap to cultivate a culture of continuous improvement, enhance operational efficiency and maintain competitiveness within volatile market contexts.

Keywords: Operational level, lean maturity model, electrical and electronic industry, lean manufacturing, Vietnam.

1. INTRODUCTION

Amidst global economic volatility, Vietnam remains a prominent Southeast Asian growth engine, with a projected GDP expansion of approximately 6.5% by 2027 [1]. Central to this momentum is the electronics sector; however, the industry currently faces systemic pressures, including intensifying global competition, rising input costs, and critical labor shortages. To sustain competitiveness, firms must move beyond macroeconomic reliance toward internal cost optimization and operational restructuring.

Lean operations have emerged as a primary strategic philosophy to enhance flexibility and eliminate waste [2]. Yet, the successful integration of lean principles remains disproportionately low [3]. Many Vietnamese electronics manufacturers adopt lean tools fragmentarily or temporarily, viewing them as transient trends rather than enduring philosophies [4]. This superficial application leads to stalled improvements, resource inefficiencies, and diminished market standing. Consequently, there is an urgent need for a comprehensive diagnostic framework that allows managers to objectively assess their current lean maturity and develop data-driven strategies for sustainable operational growth.

Current research offers various lean maturity models, ranging from the Capability Maturity Model [5] and Continuous Improvement Model [6] to specialized tools like LESAT [7] and more recent iterations [2, 8]. Despite this theoretical breadth, existing literature predominantly emphasizes strategic dimensions—such as organizational orientation and leadership philosophy—while reducing the operational level to a mere collection of improvement tools and techniques [9, 10].

This strategic bias presents a critical gap: the operational level is the primary locus of value creation and core performance. The "iceberg of ignorance" [11] underscores this disparity, noting that while frontline personnel recognize 100% of organizational problems, senior leadership identifies only approximately 4%. Consequently, for lean practices to transition from transient trends to sustainable cultures of continuous improvement, they must be rooted in operational reality [4, 12].

Within the specific context of Vietnam's electronics industry, empirical research remains fragmented. Most studies evaluate lean performance at a holistic corporate level [13], neglecting the granular operational maturity essential for long-term competitiveness. There is, therefore, an urgent need for a localized assessment framework that focuses on operational-level criteria. Such a model would enable managers to accurately diagnose their current state and implement targeted, sustainable improvement strategies.

2. LITERATURE REVIEW

2.1. Lean maturity level

Lean manufacturing represents a fundamental shift in organizational culture toward a lean paradigm. Systematic methods for evaluating and monitoring this evolutionary progress are essential for organizations to both attain and maintain a state of lean maturity [8].

Research regarding lean maturity has evolved through several distinct paradigms. The capability maturity model by Paulk [5] initially prioritized process consistency, though it is criticized for neglecting strategic, technological, and human resource dimensions. Bessant and Caffyn [6] proposed a five-stage roadmap for continuous improvement; while this model encouraged organizational-wide participation, it lacked the flexibility required for volatile production environments. Overall, the existing models have serious drawbacks; they concentrate on a thorough strategic level but lack an operational level plan, which makes them challenging to implement in a manufacturing setting. Furthermore, it is challenging to precisely quantify operational efficiency and determine maturity in the absence of specified measures.

Subsequent frameworks shifted toward systemic integration. The Lean Advancement Initiative [7] emphasized the value chain and enterprise-wide strategy but this model needs support from experts in lean. Beside that, Jørgensen [14] tracked the transition from discrete optimization to a holistic organizational culture; nevertheless, specific criteria to assess the organization's present level of Lean were still absent. Notably, these models often lacked quantitative validity or understated the critical role of leadership. More recent scholarship has sought to bridge these gaps by incorporating resource-based views—focusing on the synergy between people, technology, and processes [8] - and developing granular process measurement tools [2, 15]. According to Maasouman and Demirli [8], there are four levels of lean maturity at the operational level: understanding, implementation, improvement, sustainability. These levels are evaluated using qualitative checklists, and no thorough set of evaluation criteria is suggested for each level. Furthermore, Nguyen et al. [13] have contributed a dual-methodological approach, providing a systematic framework for both qualitative and quantitative evaluation at the organizational level. A lean maturity model is included in the aforementioned studies, but they lack specific evaluation criteria [8], [14]. Others define evaluation metrics without establishing maturity levels [16–18]. Furthermore, integrated approaches often rely exclusively on qualitative criteria [15]. As a result, Businesses are unable to precisely measure operational status or navigate a structured maturity roadmap due to the lack of a single, quantitative evaluation tool.

Collectively, existing theoretical frameworks establish a diverse foundation for maturity assessment yet exhibit notable limitations. Key shortcomings include a fragmented integration of human factors, organizational culture, and lean support systems. Furthermore, the absence of standardized measurement scales and a relative neglect of leadership at the operational level diminish the practical utility of these models within high-velocity production environments.

2.2. Key Criteria for Assessing Lean Maturity at the Operational Level

Studies on lean assessment are conducted at both strategic and operational levels.

At the strategic level, established frameworks such as the Shingo Model [19] and LESAT [7] prioritize leadership, organizational culture, and overarching strategy. However, these models often lack the granularity required to define implementation standards for frontline operators or line managers. While performance-based metrics are commonly used to gauge success, alternative methodologies like fuzzy logic have been introduced to mitigate the ambiguity and subjectivity inherent in traditional scoring systems [17]. Furthermore, the Lean Assessment Tools (LAT) framework provides a dual qualitative and quantitative model at the enterprise level [13]. Although LAT effectively evaluates organizational dimensions—including culture, customer focus, and strategic orientation, it does not sufficiently address operational-level requirements. Specifically, by omitting critical production-tier criteria such as direct labor competencies, operational leadership, and the shop-floor environment, LAT remains unable to precisely determine lean maturity at the point of value creation.

At the operational level, scholarship traditionally characterizes lean implementation as the synchronized application of technical tools and systems [9], [10]. Consequently, maturity assessments often rely on qualitative and quantitative data collection to merely verify the presence of lean methodologies [8]. This approach exhibits a fundamental limitation: it measures the existence of tools rather than their functional effectiveness. Furthermore, because improvement initiatives are typically centralized within engineering or middle management, the frontline operations team—those responsible for the daily execution of lean principles—is frequently excluded from the evaluation process. This exclusion results in a systemic oversight of the human and behavioral factors essential for the long-term sustainability of lean practices.

Strategic assessment of lean implementation at the operational level necessitates a shift from viewing lean as a technical toolkit to treating it as a foundational management philosophy. Establishing a robust lean work culture is a prerequisite for the successful deployment of synchronized systems and technical tools. To address this, the current study proposes a multidimensional lean maturity framework that integrates both qualitative and quantitative metrics specifically at the shop-floor level. Moving beyond traditional indicators like waste reduction and labor productivity, this assessment tool incorporates three additional core pillars: direct labor competencies, operational leadership, and the enabling environment that is inherited and modified from recent studies [20 - 24]. By capturing these human and contextual dimensions, the framework ensures that the lean transformation is not merely a transient tactical gain but a sustainable organizational evolution.

3. METHODOLOGY

This research adopts a multi-methodological approach [25], structured to ensure both theoretical rigor and practical validity. The study begins with a comprehensive literature review to synthesize existing lean maturity frameworks and identify specific assessment criteria relevant to the operational level. To establish content validity, the study utilizes in-depth semi-structured interviews [26] with a purposive sample of five subject matter experts. This panel—comprising directors, lean consultants, and quality executives—possesses extensive experience across the computer, consumer electronics, and telecommunications sectors. The primary objective of this phase is to refine the translated maturity scale and ensure the contextual suitability of each criterion. Interview data are analyzed for thematic convergence and consensus, with all modifications to primary and secondary criteria systematically documented to provide a transparent audit trail.

Notably, prior research has predominantly utilized case study methodologies to evaluate Lean implementation levels. For instance, Maasouman [8] examined two production cells, while Pienkowski [2] integrated management interviews within a four-company multi-case study. Similarly, Al-baldawi et al. [20] employed Likert-scale questionnaires across four Iraqi SMEs. Following Yin's [27] assertion that investigating typical cases yields higher informational value for average or standard organizations, this study adopts a case study approach involving two representative electronics firms in Ho Chi Minh City. This selection ensures that the refined assessment tool reflects common industry conditions rather than being skewed by outliers, thereby enhancing its practical applicability across the sector.

To process the resulting data, fuzzy logic is utilized as the primary analytical framework. Fuzzy logic is particularly effective in case study research for its ability to synthesize heterogeneous qualitative and quantitative datasets into cohesive metrics, such as a "leanness index" [16–18]. This approach has been validated in existing literature: Pakdil and Leonard [16] integrated 8 quantitative and 5 qualitative dimensions; Maasouman [8] applied fuzzy logic to determine performance across operational levels; and both Wankhede et al. [18] and Vinodh and Chintha [17] demonstrated its utility in quantifying leanness via linguistic variables, specifically within the electronics industry. Consequently, this study employs fuzzy logic to ensure a robust, multidimensional evaluation of lean performance. To mitigate subjectivity, qualitative dimensions are assessed via a 5-point Likert scale (ranging from "very poor" to "very good"). Concurrently, expert interview data are utilized to establish fuzzy sets, defining the "ideal" (best) and "critical" (worst) boundary values for each measurement criterion. Each primary criterion is scored based on the weighted average of its underlying sub-criteria. These results are plotted on a radar chart to provide a multidimensional visualization of the firm's current operational capabilities relative to established maturity benchmarks. The aggregate scores of all sub-criteria are synthesized to determine the overall lean maturity. Firms are then categorized according to a modified maturity scale, adapted from the framework proposed by Kreutzer, Borowski, and Isenhardt [28], allowing for precise benchmarking and strategic positioning.

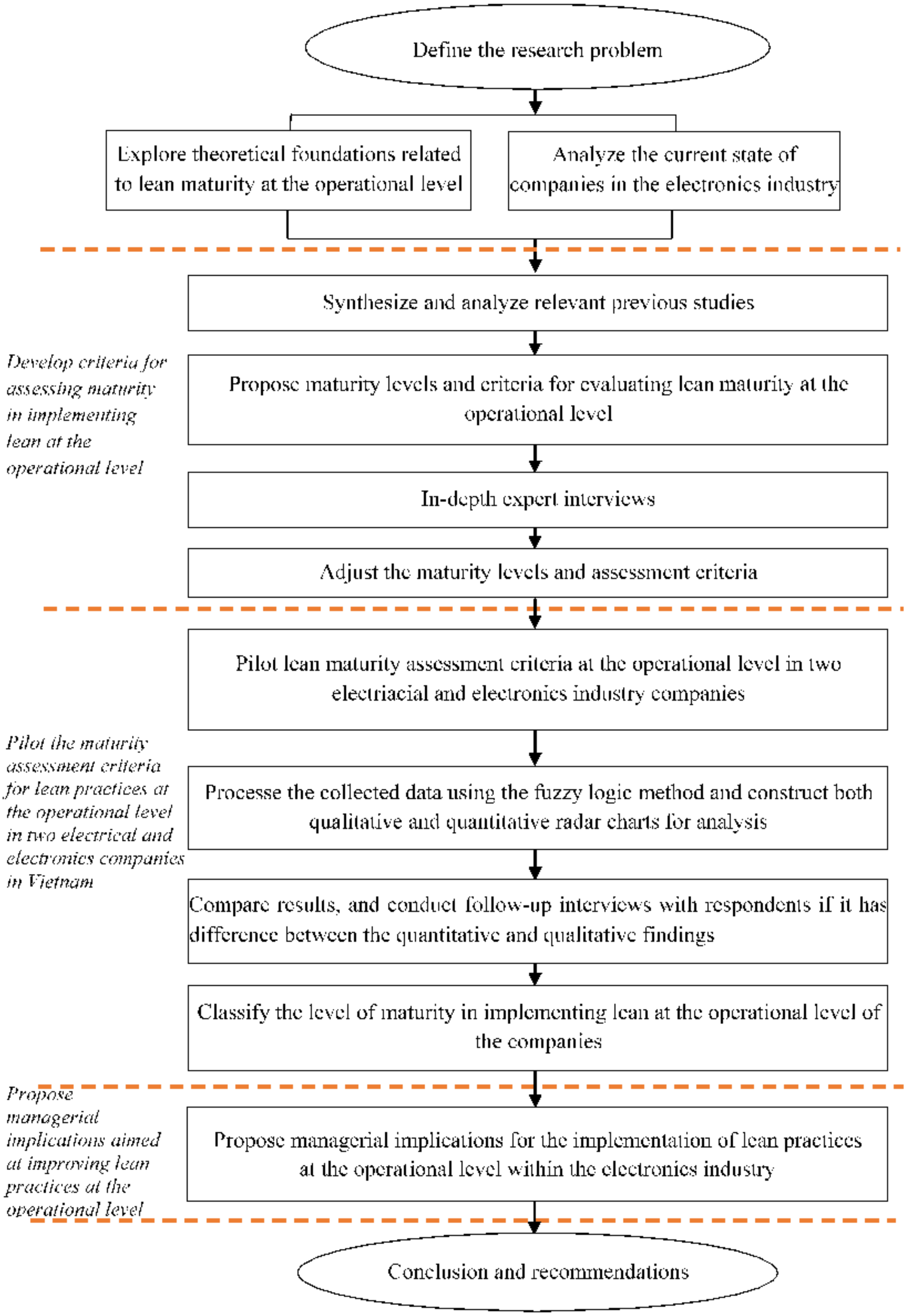

Figure 1. Research process *(Source: by authors)*

4. RESULTS AND DISCUSSION

This section outlines the refinement of the operational-level lean maturity assessment criteria tailored for the electrical and electronics sector. Furthermore, it demonstrates the empirical application of these validated criteria through a comparative analysis of two representative enterprises, company X and company Y, operating within the Vietnamese electronics manufacturing industry.

4.1. Results of Lean Maturity Assessment Criteria at the Operational Level

Drawing on foundational research in lean maturity [8], [13], [20], [29], this study develops a specialized assessment framework for the operational level. The model's core structure adopts the six primary dimensions proposed by Maasouman and Demirli [8], which are subsequently refined through in-depth expert interviews. To ensure comprehensive coverage, these dimensions are augmented with supplementary criteria synthesized from the broader literature [16], [18], [30], resulting in a contextually validated instrument for operational evaluation.

Following the methodology of Creswell and Creswell [25], this study conducts in-depth interviews with a purposive sample of five electronics industry experts to refine and validate the assessment framework. The final instrument comprises six primary dimensions and 57 sub-indicators (see Appendix A). These dimensions are categorized as follows: operators (12 indicators), work environment (9 indicators), quality (11 indicators), equipment utilization (7 indicators), processes (7 indicators), and frontline management (11 indicators).

Adopting the framework proposed by Maasouman and Demirli [8], this study utilizes a four-stage maturity model comprising understanding, implementation, improvement, and sustainability. These levels serve as a longitudinal measure of the evolution of a continuous improvement culture. To ensure granular diagnostic capabilities, this classification is mapped across six primary criteria and 57 sub-criteria synthesized from contemporary literature [8, 15, 16, 18, 20–24]. These criteria are further calibrated through in-depth interviews with 5 experts to ensure alignment with the specific operational realities of the electronics industry in Vietnam. The resulting assessment data are visualized via radar charts, which transform multifaceted qualitative and quantitative inputs into a cohesive visual overview. This allows management to rapidly identify operational bottlenecks and formulate data-driven strategic decisions. Ultimately, this approach establishes a localized improvement roadmap, providing a structured trajectory for enterprises to transition from foundational awareness to self-sustaining Lean maturity.

4.2. Discussion

To ensure empirical validity and sectoral representativeness, two case studies are selected from the electronics industry based on accessibility, organizational consensus for collaborative assessment, and market positioning. The selected firms represent the three primary segments of the electronics sector: computing, consumer electronics, and telecommunications.

As an ultimate global technology corporation, company X specializes in the design and manufacture of semiconductors and microprocessors. With a dominant market share of approximately 71.9% (as of Quarter 2/2024), company X operates across the computing, consumer electronics, and telecommunications segments. Despite its market leadership, the firm faces systemic industry challenges, making it an ideal case for identifying operational gaps in lean implementation.

Company Y is a global leader in automated data collection and factory automation, specifically manufacturing high-precision barcode readers and mobile computers. Its products command over 50% of the global retail market and are integral to high-capacity logistics, healthcare, and aviation. The analysis of company Y provides insights into lean maturity within highly specialized, automated production environments.

Direct observation, data from internal company systems, and qualitative information from surveys are used to gather analysis results. Data validation for respondent outlier responses and in-depth interviews with regional managers come next.

Both companies, X and Y, attained comparatively high levels of lean maturity, according to the analysis results (Figures 2 and 3), although there is still room for improvement:

- Operators and frontline managers are the two criteria with the lowest scores in company X. This shows that in order to support sustained improvement, there is an urgent need to increase operators' involvement and role as well as direct management's dedication and direction.

- Operators, work environment, and frontline managers are the three criteria with the lowest outcomes for company Y, while earning very high lean scores in some categories (showing process efficiency and consensus). This demonstrates that while the company has made strides in process improvement, it still has challenges in developing capacity and allowing staff members to actively engage in improvement initiatives. To reach a greater level of maturity, company Y must prioritize developing the skills of its operational staff and reorienting the role of frontline managers in spearheading on-site reforms.

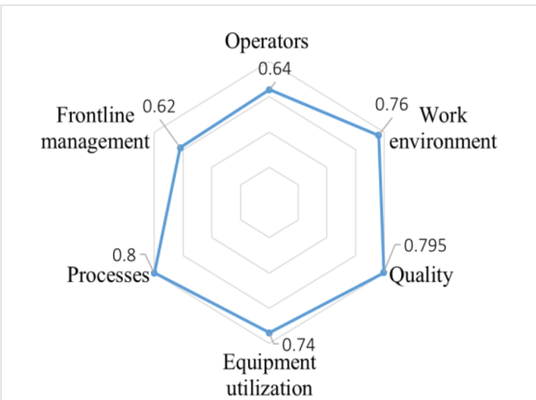

Figure 2. Radar chart of maturity criteria for company X. Source: by authors.

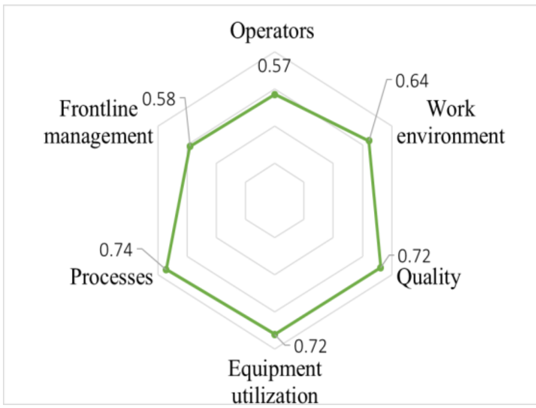

Figure 3. Radar chart of maturity criteria for company Y. Source: by authors.

This study classifies lean maturity levels by computing the average total score of six primary criteria after evaluating the current state of affairs using the evaluation criteria (Appendix A). The maturity level assessment methodology has been modified to accommodate 57 rectification indicators based on the findings of Kreutzer [28]. The evaluation data is brought to the range [0, 1] using the fuzzy normalization method. Understanding (0–0.25), implementation (0.26–0.50), improvement (0.51–0.75), and sustainability (0.76–1.00) are the four lean maturity stages according to this scale. Particularly, company X's average total score for the six adjusted criteria is 0.73, which is the upper limit of level 3-improvement, while company Y's score is 0.67, which falls inside level 3-improvement (Figure 4).

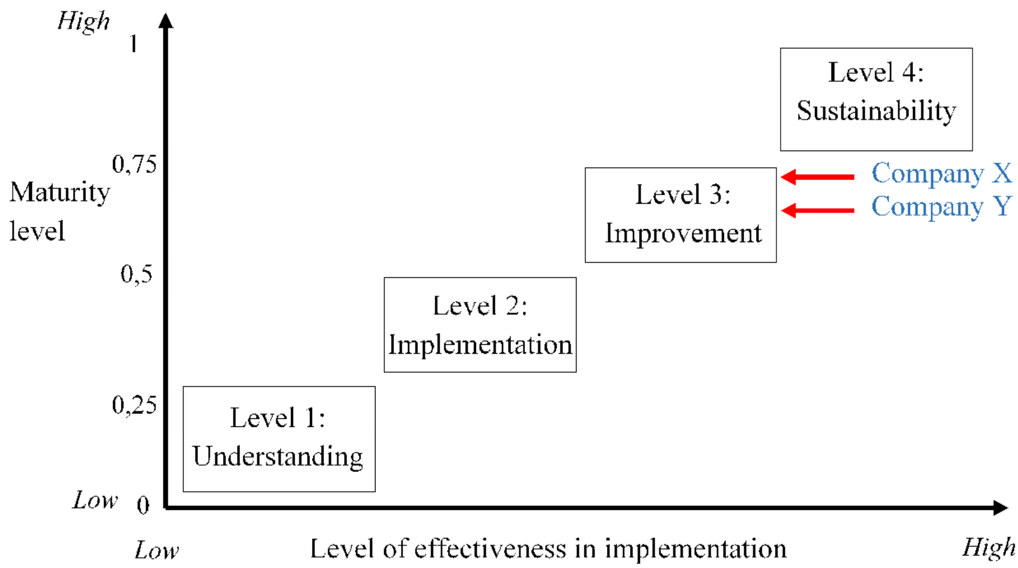

Figure 4. Lean maturity levels of company X and company Y. Source: by authors.

The notion of a Lean maturity roadmap organized as a hierarchical capacity-building framework, where mastery of core requirements is a prerequisite for establishing advanced operational capabilities, is a noteworthy contribution of this study. Four successive milestones are used to operationalize this transformation: level 1-understanding, which focuses on establishing standardized, disciplined work environments and aligning personnel perception with fundamental lean tools; level 2-implementation, which is defined by the active integration of lean techniques into daily production; level 3-improvement, which shifts the focus toward workforce empowerment and the proactive, independent elimination of waste; and level 4-sustainability, the terminal stage of maturity characterized by maximized team autonomy and the complete internalization of the lean philosophy as a self-sustaining organizational culture. The concept offers a strict pathway for moving from simple process control to a deeply rooted culture of continuous improvement by creating this stepwise trajectory.

5. CONCLUSION

This study classifies lean maturity levels by computing the average total score of six primary criteria after evaluating the existing state of affairs using the evaluation criteria (Appendix A). The maturity level scoring methodology has been modified to fit 57 corrective indications based on the findings of Kreutzer [28]. The evaluation data is converted to the range [0, 1] using the fuzzy normalization approach. Understanding (0–0.25), implementation (0.26–0.50), improvement (0.51–0.75), and sustainability (0.76–1.00) are the four levels of lean maturity based on this scale. The empirical results indicate that company X achieved an aggregate score of 0.73, positioning it at the upper threshold of the improvement phase (level 3). Similarly, company Y recorded a score of 0.67, also categorizing it within the improvement stage (Figure 4). Both had deficiencies in cultural and human elements, especially indicators pertaining to operators and frontline management at the operational level, despite scoring highly on technical criteria including quality, procedures, and equipment use.

Based on the empirical findings and the comparative analysis of companies, X and Y, the following conclusions and strategic implications are presented to guide lean maturity transitions within the Vietnamese electronics sector. To successfully transition from the "improvement" phase to "sustainability", enterprises must prioritize the synchronization of production requirements with continuous improvement initiatives. This requires a strategic pivot toward human capital development, specifically through targeted short-term training to enhance employee awareness and the implementation of robust idea-generation systems. Furthermore, organizations must reorient the role of frontline management from traditional supervision to active facilitation, thereby empowering operators and fostering a work environment conducive to autonomous problem-solving. This holistic approach ensures that lean practices are deeply embedded within the organizational culture rather than maintained as isolated technical exercises.

Although this study provides a detailed diagnostic of lean maturity in the electronics industry, there are several methodological limitations that affect its generalizability. Despite being carefully crafted, the evaluation criteria are not independently validated in specialty markets like the telecoms industry. As a result, testing in multi-segment companies might not adequately capture the particular operational peculiarities of telecommunications-specific manufacturing, which could restrict the management advice's applicability. Additionally, intrinsic subjectivities could hinder the qualitative depth offered by in-depth expert interviews, thereby affecting the findings' statistical representativeness across the larger industrial population.

Overall, the created framework offers a substantial empirical basis that enhances current domestic research, such as that of Nguyen [13] and Nguyen and Hung [31]. Future studies should broaden the scope of the investigation to include a variety of manufacturing sectors outside of electronics (such as the leather and footwear industry or in services related to trade transportation and warehouse due to their high contribution to Viet Nam's economics [1]) in order to further the conversation on lean maturity and provide a more thorough comprehension of lean methods within the Vietnamese socioeconomic context. By providing a quantitative foundation for maximizing the return on lean investments, incorporating financial measurements like cost-efficiency into the maturity indicators will further improve the approach. Lastly, capturing the changing complexities of domestic manufacturing systems requires a diversity of theoretical perspectives during the refining of these criteria.

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Appendix A

Notation	Original source	Adjusted sub-criteria	Company X				Company Y			
			Result Xi	Best	Worst	Lean value	Result Xi	Best	Worst	Lean value
		Operator				**0.64**				**0.57**
FW01	[16]	Absence rate	0.01	0.00	0.04	0.61	0.003	0.00	0.02	0.86
FW02	[16]	Total number of *improvement* idea / total number of employees in the team	0.88	2.00	0.00	0.44	0.50	0.85	0.00	0.59
FW03	[16]	Number of ideas implemented / total number of suggestions	0.77	1.00	0.00	0.77	0.20	0.60	0.00	0.33
FW04	[16]	Total number of *Lean-trained* employees in the team / total number of employees in the team	0.40	1.00	0.00	0.40	0.00	1.00	0.00	0.00
FW05	[20]	Total number of multi-functional employees in the team / total employees in the team	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00
FW06	[22]	Employees are empowered and encouraged to actively participate in the decision-making process.	3.40	5.00	1.00	0.60	3.40	5.00	1.00	0.60
FW07	[22]	*The operator is capable of working independently without direct supervision.*	3.92	5.00	1.00	0.73	3.80	5.00	1.00	0.70
FW08	[22]	*The operator is capable of working effectively in a team.*	3.76	5.00	1.00	0.69	3.32	5.00	1.00	0.58
FW09	[22]	*The operator is the one who proposes improvement ideas.*	4.16	5.00	1.00	0.79	3.80	5.00	1.00	0.70
FW10	[18]	*The operator* makes efforts to improve the process and the product.	2.32	5.00	1.00	0.33	3.56	5.00	1.00	0.64
FW11	[22]	The operator is trained in *multiple skills to perform a variety of different jobs.*	4.44	5.00	1.00	0.86	3.52	5.00	1.00	0.63

FW12	[22]	*The operator* is the one who directly solves the problem.	2.76	5.00	1.00	0.44	2.00	5.00	1.00	0.25
		Work environment				**0.76**				**0.64**
WE01	[8]	Number of accidents (or incidents) per year	0.00	0.00	1.00	1.00	1.00	0.00	2.00	0.50
WE02	[8]	Ergonomic risks	0.04	0.00	1.00	0.96	0.09	0.00	0.19	0.50
WE03	[21]	Near-miss incidents	2.00	0.00	10.00	0.80	0.00	0.00	3.00	1.00
WE04	[23]	Risk prevention measures are in place (clearly marked hazardous areas, adequate protective equipment)	4.52	5.00	1.00	0.88	3.48	5.00	1.00	0.62
WE05	[23]	Ergonomic design: Workstations match human body size and movement	4.68	5.00	1.00	0.92	3.76	5.00	1.00	0.69
WE06	[15]	*Lean tools (e.g., 5S) are applied to maintain a clean and orderly workplace*	3.60	5.00	1.00	0.65	2.64	5.00	1.00	0.41
WE07	[16]	*Optimized inventory levels of raw materials and finished goods*	2.52	5.00	1.00	0.38	4.36	5.00	1.00	0.84
WE08	[23]	Reasonable workload control to avoid exceeding workers' endurance limits	4.08	5.00	1.00	0.77	4.04	5.00	1.00	0.76
WE09	[23]	Appropriate air quality, lighting, and noise levels	4.24	5.00	1.00	0.81	2.60	5.00	1.00	0.40
		Quality				**0.80**				**0.72**
Q01	[18]	Scrap rate	0.60%	0.10%	1.50%	0.65	0.10%	0.05%	0.30%	0.79
Q02	[18]	Rework rate	0.60%	0.20%	2.00%	0.78	2.36%	2.00%	3.20%	0.70
Q03	[18]	First-pass yield	99.40%	100.00%	95.00%	0.88	97.64%	98.70%	95.50%	0.67
Q04	[16]	Employees detect defects and stop the production line	3.92	5.00	1.00	0.73	4.24	5.00	1.00	0.81
Q05	[16]	Defective parts are returned to the responsible employees for troubleshooting	4.24	5.00	1.00	0.81	4.64	5.00	1.00	0.91

Q06	[16]	*Quality inspections are performed after each stage*	4.52	5.00	1.00	0.88	3.32	5.00	1.00	0.58
Q07	[16]	*Quality inspections are performed upon product completion*	4.68	5.00	1.00	0.92	4.56	5.00	1.00	0.89
Q08	[15]	*Quality information is updated daily*	4.60	5.00	1.00	0.90	3.60	5.00	1.00	0.65
Q09	[15]	Poka-yoke is utilized to prevent errors during the production process	3.84	5.00	1.00	0.71	1.96	5.00	1.00	0.24
Q10	[15]	*Operators are committed to the quality of the output product*	4.52	5.00	1.00	0.88	4.72	5.00	1.00	0.93
Q11	[15]	*Production teams regularly implement quality improvement activities (e.g., daily/weekly improvement meetings, small-scale Kaizen)*	3.96	5.00	1.00	0.74	4.24	5.00	1.00	0.81
		Equipment utilization				**0.74**				**0.72**
F01	[20]	OEE	69.50%	80.00%	50.00%	0.65	81.96%	88.00%	65.00%	0.74
F02	[8]	Machine running time.	78.61%	86.30%	67.00%	0.60	92.47%	95.00%	85.00%	0.75
F03	[16]	Emergency unscheduled repair time / maintenance time.	26.44%	0.00%	100.00%	0.74	28.78%	0.00%	100.00%	0.71
F04	[18]	Machinery capable of producing diverse product lines.	4.08	5.00	1.00	0.77	3.28	5.00	1.00	0.57
F05	[18]	*Production equipment is* automated *to enhance productivity*	4.60	5.00	1.00	0.90	3.12	5.00	1.00	0.53
F06	[15]	*Applying Total Productive Maintenance (TPM) measures to minimize unscheduled breakdowns.*	3.88	5.00	1.00	0.72	4.28	5.00	1.00	0.82
F07	[20]	*Implementing measures to reduce changeover time between different product lines (e.g., SMED, etc.).*	4.48	5.00	1.00	0.87	4.64	5.00	1.00	0.91
		Processes				**0.80**				**0.74**
P01	[8]	Value-added ratio for products.	0.86	0.90	0.70	0.79	0.89	0.93	0.82	0.65

P02	[8]	Total on-time deliveries divided by total orders.	0.96	1.00	0.70	0.86	0.95	1.00	0.88	0.60
P03	[8]	Balancing efficiency.	1.01	1.02	0.97	0.70	1.53	0.01	0.90	1.00
P04	[16]	*Utilizing data and statistical methods to control and improve processes.*	4.24	5.00	1.00	0.81	3.76	5.00	1.00	0.69
P05	[15]	*Developing and adhering to standard operating procedures for all tasks.*	4.04	5.00	1.00	0.76	4.36	5.00	1.00	0.84
P06	[15]	*Implementing Kanban as a visual tool to signal production demand between stages*	4.20	5.00	1.00	0.80	4.12	5.00	1.00	0.78
P07	[18]	Solving problems by identifying the root causes.	4.32	5.00	1.00	0.83	3.56	5.00	1.00	0.64
		Frontline management				**0.62**				**0.58**
FL01	[24]	*Frontline managers* are capable of identifying what delivers value to achieve *the team's common goals*.	4.00	5.00	1.00	0.75	4.40	5.00	1.00	0.85
FL02	[24]	*Frontline managers possess the competency to support continuous improvement activities for their teams.*	4.00	5.00	1.00	0.75	2.64	5.00	1.00	0.41
FL03	[24]	*Frontline managers have the ability to manage people and ensure appropriate task allocation.*	4.40	5.00	1.00	0.85	4.48	5.00	1.00	0.87
FL04	[24]	*Frontline managers are competent in identifying and supporting workers in implementing improvement ideas to eliminate waste.*	3.52	5.00	1.00	0.63	2.92	5.00	1.00	0.48
FL05	[22]	*Frontline managers leverage daily opportunities to coach and support team members* on Lean ideas and tools.	1.64	5.00	1.00	0.16	2.36	5.00	1.00	0.34
FL06	[24]	*Frontline managers conduct ongoing assessments of team members to drive perpetual improvement.*	3.52	5.00	1.00	0.63	2.48	5.00	1.00	0.37

FL07	[24]	*Frontline managers empower team members to take responsibility for improving their own job.*	3.60	5.00	1.00	0.65	3.60	5.00	1.00	0.65
FL08	[24]	*Frontline managers* reinforce daily maintenance practices to *ensure operational stability.*	4.04	5.00	1.00	0.76	3.72	5.00	1.00	0.68
FL09	[24]	*Frontline managers motivate and remind staff to apply a continuous improvement mindset to enhance productivity.*	1.92	5.00	1.00	0.23	2.04	5.00	1.00	0.26
FL10	[24]	*Frontline managers* promote and facilitate teamwork among members.	3.88	5.00	1.00	0.72	3.76	5.00	1.00	0.69
FL11	[22]	*Frontline managers* focus on the personal and professional development of team members.	3.76	5.00	1.00	0.69	4.20	5.00	1.00	0.80

Note: Italicized text indicates content that has been adjusted from the original criteria through in-depth expert interviews.

Conflict of Interest

The authors affirm that there is no conflict of interest associated with the publication of this article. All authors agree with the content of the article and the order in which the authors are presented.

Declaration

This manuscript is original, has not been published before, and is not currently being considered for publication elsewhere.