GLOBAL BUSINESS MANAGEMENT REVIEW
http://e-journal.uum.edu.my/index.php/gbmr

How to cite this article:
Wong, S.W., & Nadarajah, G. (2025). The effect of lean management practices towards operational performance of semiconductor firms in Penang: A case of integrative mechanism. *Global Business Management Review, 17*(1), 96-117. https://doi.org/10.32890/gbmr2025.17.1.5

THE EFFECT OF LEAN MANAGEMENT PRACTICES TOWARDS OPERATIONAL PERFORMANCE OF SEMICONDUCTOR FIRMS IN PENANG: A CASE OF INTEGRATIVE MECHANISM

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Received: 14/11/2024 Revised: 05/03/2025 Accepted: 24/03/2025 Published: 30/06/2025

ABSTRACT

Introduction: The existing body of literature indicates that lean management is a comprehensive concept, originating from the Toyota Production System, and encompassing various typologies. This research subsumed all the lean typologies into a holistic model of lean management practices encompassing lean manufacturing concepts and frameworks, lean tools and techniques, and lean activities, as critical dimensions. Similarly, the literature showed that the effect of lean management practices on operational performance was investigated in isolation, with little focus on the impact of intervening variables in this research stream. Drawing supported by System Theory and Resource Based View (RBV), this research investigates the effect of lean management practices on operational performance, with integrative mechanisms as mediating variables, in an entirely new context (Semiconductor firms in Penang, Malaysia).

Objectives: The research aimed to empirically investigate the effect of Lean manufacturing concepts and frameworks, Lean tools and techniques, and Lean activities on operational performance. As well, the research aimed to empirically investigate the mediating effect of integrative mechanisms on the relationship between Lean manufacturing concepts and frameworks, Lean tools and techniques, Lean activities, and operational performance.

Methods: This study employs a quantitative approach based on a cross-sectional design, focusing on data collection from randomly selected employees of semiconductor firms in Penang through a

systematic sampling technique. The primary objective is to examine cause-and-effect relationships between variables. Therefore, the population of the study is 100,000 employees and the sample size is 382 employees. While a well-structured questionnaire was used to collect responses and research data was analyzed using SPSS (statistical package for social sciences) and PLS-SEM (partial least squares-structural equation modeling).

Results: The research finding is quite fascinating, the effect of Lean management practices on operational performance and integrative mechanisms has been empirically established. Accordingly, the research finding provided statistical support for the indirect effect of lean management practices on operational performance, through integrative mechanisms. Hence, seven (7) direct and three (3) indirect hypothesized effects were statistically supported.

Conclusion: In conclusion, this research accentuated the efficacy of lean management practices as a significant driver of operational performance and integrative mechanisms within organizational settings. The implication is that firms can adopt lean as a tool to integrate internal work processes and achieve operational excellence.

Keywords: *Operational performance, Lean manufacturing concepts and frameworks, Lean tools and techniques, Lean activities, Integrative mechanism,*

1.0 INTRODUCTION

Operational performance is key for business organizations to increase profitability (Mathiyazhagan et al., 2021), enhance financial performance (Ariadi, Surachman, Sumiati & Rohman, 2021), and achieve sustainable growth (Maldonado-Guzmán et al., 2023). Operational performance is also critical for organizational success (Reynders, Kumar & Found, 2022), and development (Kumar, Babu & Paranitharan, 2022a; Pearce et al., 2021). However, many companies were unable to achieve optimum performance levels. Accordingly, literature established that firms adopt lean management practices to achieve sustainable operational performance (Panigrahi et al., 2023). However, a comprehensive framework for lean management has yet to be established, largely due to the perception that the lean system is a multifaceted concept encompassing various typologies, including Total Quality Management (TQM), the pull-production system, and just-in-time (which emphasizes the rapid production and delivery of precise product quantities to customers), Muda (elimination of waste), process-set-up time reduction, preventive equipment maintenance, and Single Minutes Exchange Dies (Ali & Kuan, 2023; Afum et al., 2022; Aquilani et al., 2017); as well as Heijunka (creation of efficient production process), Jidoka (ability to use machines and detect/prevent defects during production), and Kaizen (continuous improvement), six sigma (technique of problem solving during production), 5S methodology (creating a clean, organized and efficient work environment), value stream mapping (visual representation of flow of information, activities and materials to deliver to customers), Andon (real-time communication to signal abnormalities and enhance production efficiency), Kanban (inventory control system to ensure smooth flow of materials), standardization (automated method of performing tasks), productive maintenance (proactive culture of maintaining equipment, minimizing cost and preventing breakdown during production process) and Poka-Yoke (proofing technique of minimizing errors/defects), Gemba and Genchi Genbutsu (technique of using experience and current contextual conditions to achieve production efficiency), Kaizen events and problem

solving (Ahmed, Mathrani & Jayamaha, 2024; Oliveira et al., 2022; Kamble & Gunasekaran, 2021). Accordingly, this study examines the impact of a comprehensive model of lean management practices on operational performance.

Although the positive and significant impact of lean management practices on operational performance has been well-established across various contexts (Panigrahi et al., 2023; Kumar, Singh & Jain, 2022b), limited research has explored this relationship through a mediating variable (Fokalie & Siagian, 2021). More so, the indirect effect was only established at the construct level, neglecting the multi-faceted nature of lean management practices. Equally, Maldonado-Guzmán et al. (2023) suggested the need for testing the effect of a mediator on lean management practices and operational performance research. This research intends to fill this paucity, by using integrative mechanisms as mediators on the relationship between lean management practices – lean manufacturing concepts and frameworks, lean tools and techniques lean activities, and operational performance. Based on this assertion, the effect of different facets of integrative mechanisms such as supply chain integration (Al-Dweiri et al., 2024), intra-organizational integration (Arellano, Rebolledo & Tao, 2019), strategic supplier and customer integration (Ariadi, Surachman, Sumiati & Rohman, 2021) and employee integration (Graham, Cadden & Treacy, 2023) on operational performance has reported as positive and significant. Accordingly, this study aims to investigate the mediating role of integrative mechanisms in the relationship between lean management practices and operational performance among semiconductor firms in Penang.

2.0 LITERATURE REVIEW

According to the literature, lean management is a broad typology that originated from the Toyota production system (Ahmed, Mathrani & Jayamaha, 2024) and symbolizes the advantage of leanness (optimum resources utilization), as well as organizational system integration/automation, to achieve operational excellence (Panigrahi et al., 2023). This underlies the importance of the resource-based view (RBV) and System Theory. According to RBV, firms that transform scarce resources in a manner that is unique and distinct from competitors, have greater opportunity to gain competitive advantage (Al-Dweiri et al., 2024). Applying this concept to a lean production system suggests that firms should optimize resource utilization to ensure the precise production and delivery of goods to customers, minimize or eliminate waste, automate production processes, facilitate real-time communication, prevent defects during manufacturing, implement effective maintenance strategies, and mitigate operational breakdowns (Maldonado-Guzmán et al., 2023; Kumar et al., 2022). Yet, the System Theory emphasizes viewing the whole organization as a system, on the ground that it is composed of different resources (human, materials, technological, and financial), structure (departments, units, and organizational hierarchy), organizational policies and procedures of performing tasks, as well as the culture of promoting creativity and innovation (Hernandez-Matias et al., 2020). Applying the system outlook to the present research implies that firms can sustain competitiveness by integrating vital components of the production process (man, machines, and materials), to facilitate teamwork/collaboration amongst employees, and institute a culture of continuous improvement/innovation (Naeem et al., 2021; Nawanir, Fernando & Lim, 2021; Romana, 2021).

Lean manufacturing concepts and frameworks, according to the literature, provide a systematic approach to enhancing operational performance, making processes more efficient, reducing costs,

and delivering greater value to customers (Ball & MacBryde, 2022; Mostafa et al., 2015). Companies that successfully implement Lean principles often experience significant improvements in their overall operational effectiveness and competitiveness in the market (Secchi & Camuffo, 2016). Existing research has demonstrated that Lean fosters a culture of continuous improvement, wherein employees across all organizational levels are encouraged to identify and implement incremental enhancements in their daily tasks. This ongoing refinement of processes contributes to enhanced operational efficiency and superior product quality (Onofrei et al., 2019). The Just-in-Time (JIT) approach is designed to synchronize production with actual demand, ensuring that items are manufactured precisely when needed within the production process. By minimizing inventory levels and producing goods in response to real-time demand, firms can significantly reduce costs associated with excess stock and material storage (Saleh et al., 2018). A comprehensive understanding of Lean concepts and frameworks is essential, as it directly informs the selection of an appropriate methodological approach to optimize productivity outcomes (Onofrei et al., 2019; Secchi & Camuffo, 2016).

However, the successful implementation of Lean is contingent upon the careful selection of practices and applications within the Lean system (Bednarek & Luna, 2008). Many firms have adopted and applied Lean methodologies in ways that are unique to their organizational structures, often without possessing a thorough understanding of Lean principles or conducting a comprehensive assessment of the alignment between Lean practices and their specific operational processes. This gap in knowledge and strategic application has hindered the effective deployment of Lean methodologies in achieving optimal performance improvements (Maware & Parsley, 2022; Mostafa et al., 2015). While Lean manufacturing concepts and frameworks are regarded as beneficial, there can be challenges and negative aspects associated with their implementation (Secchi & Camuffo, 2016). Lean strategies often prioritize cost reduction, which can lead to cutting corners or reducing resources to an extent where it negatively affects product quality or employee well-being. Implementing Lean practices often requires significant changes in organizational culture and work processes. Employees or management may resist these changes, leading to implementation failures or reduced morale. Based on the above narration of extant literature, thus, the study postulated that:

H1: Lean concepts and frameworks have a significant effect on operational performance

Ali and Kuan (2023) emphasize that the effective deployment of lean tools and techniques is fundamental to achieving sustainable lean performance. This perspective underscores the importance of selecting the appropriate tools and methodologies to address specific challenges within the production system, thereby directly enhancing operational performance. Similarly, Tapping (2006) contends that organizations that restrict the number of lean tools at their disposal inherently constrain their ability to resolve problems and optimize processes. In contrast, firms that maintain a more extensive inventory of lean tools enable employees to draw upon a diverse range of solutions, facilitating more agile and effective problem-solving.

However, it is crucial to recognize that the mere availability of lean tools is not the sole determinant of success. An organization's ability to provide structured, real-time coaching and decision support on the appropriate application of these tools is equally critical in ensuring swift problem resolution and process enhancement (Mahajan et al., 2019). Despite these assertions, it is evident that the

application of lean tools and techniques alone does not guarantee the successful implementation of lean methodologies. Several human or "soft" factors significantly influence the effectiveness of lean adoption in manufacturing environments (Mahajan et al., 2019). Sinnicks (2005) further argues that lean tools and techniques constitute only a minor component of a broader lean intervention, with human and organizational factors serving as the primary determinants of lean success. Drawing upon the synthesis of the extant literature, this study thus postulates that:

H2: Lean tools and techniques have a significant effect on operational performance

Furthermore, lean practices emphasize the adoption of Gemba and Genchi Genbutsu, two fundamental principles within the Lean philosophy, both rooted in Japanese concepts that stress the necessity of direct observation at the site of operations to gain a deeper understanding and drive process improvements (Moyano-Fuentes et al., 2021). The term **Gemba**, which translates to "the real place" or "the actual place" in Japanese, refers to the specific location where value creation occurs within a business context. This may include the factory floor, shop floor, service desk, or any operational setting where work is actively performed. It could be a physical location in manufacturing or a specific process step in a service-oriented industry. On the other hand, Genchi Genbutsu translates to "go and see for yourself" or "go to the source." Hence, managers and decision-makers go to Gemba to observe work processes, understand the challenges, and gather real-time information. By being physically present where the work is done, managers gain insights into the actual workflow, through interactions and understanding the difficulties faced by employees. Issues and inefficiencies are better understood when observed in the context of the actual work environment, enabling more effective problem-solving methodology and achieving a better operational performance (Panigrahi et al., 2023). Based on the above narration of extant literature, thus, the study postulated that:

H3: Lean activities have a significant effect on operational performance

Furthermore, the literature showed that lean management practices provide a systematic approach to enhancing operational performance, by making production processes more efficient, reducing costs, and delivering greater value to customers (Al-Dweiri et al., 2024; Mostafa et al., 2015). However, the successful implementation of Lean is contingent upon the strategic selection of lean practices tailored to an organization's specific operational context. Managers must adopt integrative mechanisms by acquiring the requisite knowledge and comprehension of lean applications to ensure effective execution (Maware & Parsley, 2022). Furthermore, Antonio and Kusumastuti (2019) emphasize that firms that have experienced substantial performance improvements following the adoption of lean operations have integrated key mechanisms such as management commitment and involvement, teamwork, effective communication, cultural-change management, and the sustainability of continuous improvement initiatives. Consequently, enhancing performance levels necessitates leveraging information technology, optimizing the raw material delivery system, and minimizing lead times to streamline operations and reinforce lean efficiency. Accordingly, Ahmed et al. (2024), Fokali & Siagian (2021), and Akanmu & Nordin (2022) established that lean concepts and framework, lean tools and techniques and lean activities can have a positive effect on diverse segments of integrative mechanisms. Still, Arellanoa et al. (2019) and Ariadi et al. (2021) established that lean operations enhance the integrative capabilities of firms, by providing an opportunity to use

agile operational techniques and integrate with strategic partners. Based on these assertions, the following hypotheses were postulated:

H4: Lean concepts and frameworks exert a significant impact on integrative mechanisms.

H5: Lean tools and techniques have a significant effect on integrative mechanisms.

H6: Lean activities play a crucial role in shaping integrative mechanisms.

Integrative mechanisms involve strategic processes that organizations use to integrate various aspects of their operations, such as different departments, functions, or business units (Reynders et al., 2022). These mechanisms facilitate communication, collaboration, and coordination among various parts of the organization, and when implemented effectively, integrative mechanisms can have positive and significant impacts on operational performance. Integrative mechanisms promote open communication channels between different departments and teams, by ensuring that information, ideas, and feedback flow freely, reducing misunderstandings and enhancing overall operational efficiency. Again, integrative mechanisms help promote collaboration by aligning activities and initiatives across various organizational units. Equally, enhanced coordination ensures that efforts are synchronized, preventing duplication of work, and optimizing resource allocation. Therefore, integrative mechanisms facilitate the sharing of knowledge and expertise across the organization, as employees can learn from each other, leading to increased innovation, problem-solving, and operational performance.

Additionally, Singh et al. (2022) contend that integrative mechanisms promote a sense of belonging and collaboration among employees in different areas of the organization. Leading to higher morale, increased job satisfaction and teamwork, fostering a positive organizational culture that further boosts operational performance. Integrative mechanisms provide a unified framework for measuring performance across departments or units. This unified measurement approach ensures consistency and fairness, enabling the organization to identify areas of improvement and recognize successful efforts (Unzueta et al., 2020). Similarly, integrative mechanisms create a cohesive organizational structure where different functions of the company work together synergistically (Tortorella et al., 2018). This collaborative environment fosters efficiency, innovation, and adaptability, all of which contribute significantly to improved operational performance. Hence, organizations that effectively implement integrative mechanisms are better positioned to navigate challenges, capitalize on opportunities, and achieve sustainable growth. Based on the above narration of extant literature, thus, the study postulated that:

H7: Integrative mechanisms exert a significant influence on operational performance.

H8: Integrative mechanisms serve as a mediating variable in the relationship between lean concepts and frameworks and operational performance.

H9: Integrative mechanisms mediate the relationship between lean tools and techniques and operational performance.

H10: Integrative mechanisms function as a mediator in the relationship between lean activities and operational performance.

3.0 METHODS

The rationale of this study is to examine the impact of three key lean practices on firm operational performance, with integrative mechanisms serving as a mediating variable. Consequently, a quantitative research approach and a cross-sectional research design were deemed the most appropriate methodological choices. These approaches facilitate the systematic collection of responses from a representative sample of the population and enable analysis at a single point in time, thereby ensuring empirical rigor and generalizability of findings (Sekaran & Bougie, 2013). As such, 100,000 employees of Semiconductor firms in Penang, Malaysia, constituted the population, and the sample size is 382 employees, according to Krejcei and Morgan (1970). The study adopted a systematic sampling technique in the sample selection. While the research instrument was adopted from prior studies – operational performance (Melnyk et al., 2004), lean manufacturing concepts and frameworks (Shah & Ward, 2007), lean tools and techniques (Shah & Ward, 2003), lean activities (Shah & Ward, 2003) and integrative mechanisms (Shah & Ward, 2007). The research data was analyzed using the Statistical Package for the Social Sciences (SPSS) and Partial Least Squares-Structural Equation Modeling (PLS-SEM). Specifically, SPSS was employed to assess non-response bias, common method variance, and correlation analysis, ensuring data integrity, and mitigating potential biases. Meanwhile, PLS-SEM was utilized to evaluate both the measurement model—establishing the validity and reliability of research instruments—and the structural model, which involved testing the hypothesized relationships. Given the sample size considerations, a total of 382 questionnaires were distributed to the target respondents. Of these, 259 completed questionnaires were successfully retrieved, while 123 remained unreturned, resulting in an overall response rate of 67.8%.

4.0 DATA ANALYSIS & FINDINGS

Profile of Respondents

Table 4.1 shows that 247 respondents participated in the survey. Based on the outcome, male respondents were 179, and the majority accounted for 72.5% of respondents; on the other hand, female respondents were 68 which accounted for 27.5% of the total respondents. The results of descriptive statistics showed that most respondents are above 40 years, as the respondents whose age falls within 41-50 years were 74, accounting for 30% of the total respondents. Yet, the result showed that 54 respondents constituted the second majority, with age bracket of 19-30, followed by 45 respondents in the age bracket above 50, and 42 respondents in the age bracket 31-40, respectively: accounting for 21.9%, 18.2% and 17% of the total respondents.

Similarly, the results of descriptive statistics showed that most respondents are Malays, followed by Chinese and other tribes, accounting for 23.5%, 21.9%, and 21.1% of the total respondents. While Indians and those of Bumiputra Sabah and Sarawak extraction have the least frequency (43 and 40), accounting for 17.4% and 16.2% of the respondents. In terms of work experience, most respondents (98 individuals, representing 39.7%) have 11–20 years of professional experience, followed by 79 respondents (32%) with more than 20 years of experience. Regarding tenure within the current organization, the results indicate that most respondents (95 individuals, accounting for 38.5%) have been employed in their organization for over 20 years, followed by 87 respondents (35.2%) with a tenure of 11–20 years. Additionally, 38 respondents (15.4%) have been working in their organization

for 1–5 years, while 27 respondents (10.9%) have a tenure of 6–10 years. Furthermore, the descriptive statistical analysis of educational qualifications revealed that the largest proportion of respondents (61 individuals, or 24.7%) hold a bachelor's degree. Additionally, 55 respondents (22.3%) possess Postgraduate qualifications, while an equal number (55 respondents, 22.3%) hold STPM/HSC/A-Level certifications. Moreover, 46 respondents (18.6%) have a Diploma, and 30 respondents (12.1%) possess SPM/MCE/O-Level qualifications.

Table 4.1

Respondent's Profile

Variables		**Frequency**	**Percentage**
Gender	Male	179	72.5
	Female	68	27.5
Age	Under 19 years	32	13.0
	19-30 years	54	21.9
	31-40 years	42	17.0
	41-50 years	74	30.0
	Above 50 years	45	18.2
Ethnic Group	Malay	58	23.5
	Chinese	54	21.9
	Indian	43	17.4
	Bumiputra Sabah & Sarawak	40	16.2
	Others	52	21.1
Working Experience	1-5 years	35	14.2
	6- 10 years	35	14.2
	11– 20 years	98	39.7
	More than 20 years	79	32.0
Experience in Present Organization	1-5 years	38	15.4
	6- 10 years	27	10.9
	11– 20 years	87	35.2
	More than 20 years	95	38.5
Educational Qualification	SPM/MCE/O-LEVEL	30	12.1
	STPM/HSC/A-LEVEL	55	22.3
	Diploma Level	46	18.6
	First Degree	61	24.7
	Postgraduate	55	22.3

Assessment of Measurement and Structural Models

This study employed the Partial Least Squares Structural Equation Modeling (PLS-SEM) technique to assess the measurement model, structural model, and predictive relevance. As noted by Hair et al. (2014), PLS-SEM is a robust and flexible statistical technique particularly suited for evaluating complex

models and analyzing cause-and-effect relationships among variables. Its advantages over other statistical techniques stem from its superior estimation power, making it a preferred method for examining intricate research frameworks. PLS-SEM integrates principles from both partial least squares regression and structural equation modeling, enabling the simultaneous assessment of latent (unobserved) variables and their relationships with observed indicators (Chin, 1998). Figure 4.1 below illustrates the conceptual research model underpinning this study.

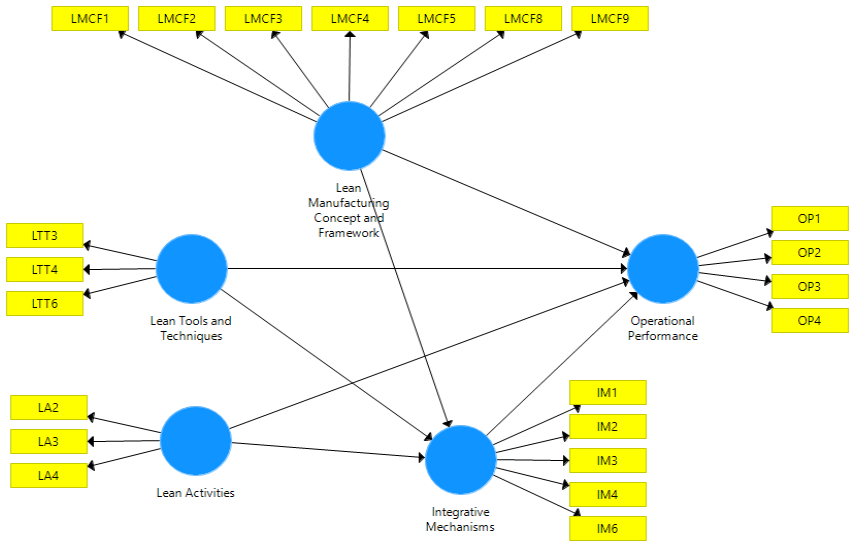

Figure 4.1 Research Model

The research model, in this study, was assessed as a reflective model – which is a critical way of establishing how reliable and valid, the items are or otherwise in reflecting each latent variable in research (Hair et al., 2014). In the context of structural equation modeling (SEM), a reflective model refers to a type of measurement model where latent constructs are assumed to cause the measured (observed) variables. It is also known as a formative measurement model. Reflective models are commonly used in fields such as psychology, sociology, marketing, and management, where researchers aim to understand underlying constructs that cannot be directly observed. They are particularly suitable for modeling constructs that are conceptualized as causing changes in the measured variables, such as attitudes or personality traits (Kline, 2011). Reliability denotes to the ability of items or indicators to consistently measure a variable over time (internal consistency of measures). While validity denotes the ability of items or indicators to be error-free and accurate in measuring a latent variable, through convergent and discriminant validity (Hair et al., 2014). Figure 4.2 shows the result of the measurement model assessment.

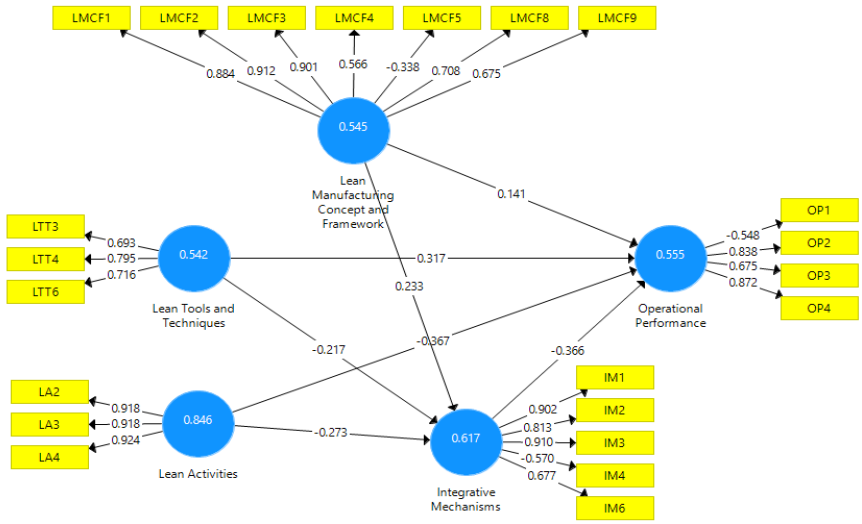

Figure 4.2 Measurement Model

The findings presented in Table 4.2 indicate that all latent variables demonstrate satisfactory reliability and validity. Notably, the composite reliability (CR) and average variance extracted (AVE) values surpass the recommended thresholds of 0.65 and 0.51, respectively, confirming the robustness of the measurement model. According to the outcome, operational performance has composite reliability and AVE of 0.655 and 0.555. On the other hand, lean manufacturing concepts and frameworks have composite reliability and AVE of 0.854 and 0.545; lean tools and techniques have composite reliability and AVE of 0.779 and 0.542; and lean activities have composite reliability and AVE of 0.943 and 0.846. In contrast, integrative mechanisms have composite reliability and AVE of 0.797 and 0.617. Thus, the level of reliability and validity for all the latent constructs in this research are satisfactory because they are above the recommended threshold value.

Table 4.2

Reliability and Validity of Instrument

	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Integrative Mechanisms	0.603	0.797	0.617
Lean Activities	0.909	0.943	0.846
Lean Manufacturing Concept and Framework	0.771	0.854	0.545
Lean Tools and Techniques	0.580	0.779	0.542
Operational Performance	0.513	0.655	0.555

Likewise, the results presented in Table 4.3 indicate that, based on the Fornell-Larcker Criterion, all latent variables exhibit a sufficient level of validity. According to the outcome, operational performance has the highest loading in its construct both in row and column (0.745). Likewise, lean manufacturing concepts and framework have the highest loading in its construct both in row and column (0.738); lean tools and techniques have the highest loading in its construct both in row and column (0.736); and lean activities have the highest loading in its construct both in row and column (0.920). Yet, integrative mechanisms have the highest loading in their construct both in rows and columns (0.786). Therefore, the validity of all latent constructs in this study is deemed satisfactory, as each construct exhibits high factor loadings within its respective row and column.

Table 4.3

Fornell-Larcker Criterion

	Integrative Mechanisms	Lean Activities	Lean Manufacturing Concept and Framework	Lean Tools and Techniques	Operational Performance
Integrative Mechanisms	0.786				
Lean Activities	-0.425	0.920			
Lean Manufacturing Concept and Framework	0.374	-0.605	0.738		
Lean Tools and Techniques	-0.204	0.049	0.112	0.736	
Operational Performance	-0.222	-0.281	0.261	0.389	0.745

In the domain of structural equation modeling (SEM) and advanced statistical analyses, the structural model constitutes the component that delineates the relationships among latent (unobserved) variables (Tabachnick & Fidell, 2007). It is typically estimated concurrently with the measurement model, which specifies the associations between latent constructs and their observed indicators. Collectively, these two models form a comprehensive SEM framework, enabling researchers to evaluate complex theoretical relationships and test hypotheses regarding latent variable interactions (Kline, 2011). To evaluate the structural model, this study employed the bootstrapping technique within PLS-SEM, given its capacity to assess causal relationships among exogenous and endogenous variables. The evaluation was conducted through key statistical metrics, including path coefficients, R-squared values, effect size (f^2), and predictive relevance (Q^2), ensuring a rigorous and robust assessment of the hypothesized relationships. Accordingly, Figure 4.3 shows the results of the direct hypotheses tested on the influence of Lean manufacturing concepts and frameworks, Lean tools &

techniques, Lean activities on semiconductors firm operational performance, as well as integrative mechanisms influence on firm operational performance.

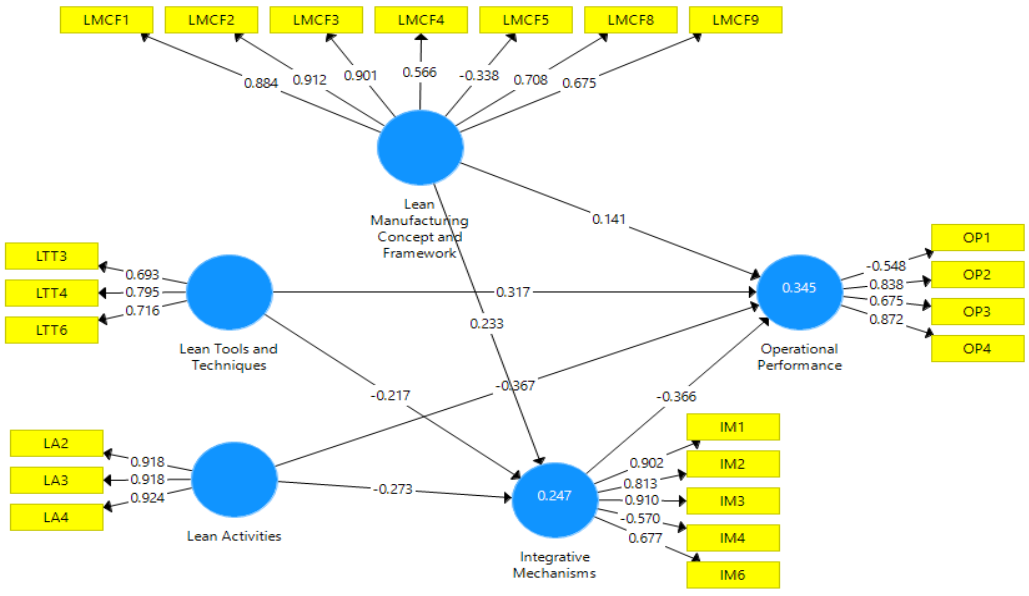

Figure 4.3 Structural Model

Table 4.4 presents the results of the hypothesis testing, indicating empirical support for the proposed relationships. Specifically, H1, which posits that lean manufacturing concepts and frameworks exert a significant effect on operational performance, is supported ($\beta = 0.141$; $t = 1.637$; $p < 0.05$). Similarly, H2, which hypothesizes that lean tools and techniques have a significant impact on operational performance, is confirmed ($\beta = 0.317$; $t = 5.739$; $p < 0.001$). Likewise, H3, which postulates that lean activities significantly influence operational performance, is also supported ($\beta = -0.367$; $t = 5.514$; $p < 0.001$). Additionally, the findings validate the influence of lean practices on integrative mechanisms. H4, which asserts that lean manufacturing concepts and frameworks have a significant effect on integrative mechanisms, is supported ($\beta = 0.233$; $t = 3.690$; $p < 0.001$). Likewise, H5, which posits that lean tools and techniques significantly impact integrative mechanisms, is confirmed ($\beta = -0.217$; $t = 4.068$; $p < 0.001$). Similarly, H6, which hypothesizes that lean activities significantly affect integrative mechanisms, is supported ($\beta = -0.273$; $t = 3.434$; $p < 0.001$).

Furthermore, the results substantiate H7, which suggests that integrative mechanisms exert a significant effect on operational performance, with empirical support ($\beta = -0.366$; $t = 5.085$; $p < 0.001$). These findings underscore the pivotal role of lean practices and integrative mechanisms in shaping operational performance outcomes.

Table 4.4

Path Coefficients (Direct effect)

	Original Sample (O)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Integrative Mechanisms -> Operational Performance	-0.366	0.072	5.085	0.000
Lean Activities -> Integrative Mechanisms	-0.273	0.080	3.434	0.000
Lean Activities -> Operational Performance	-0.367	0.066	5.514	0.000
Lean Manufacturing Concept and Framework -> Integrative Mechanisms	0.233	0.063	3.690	0.000
Lean Manufacturing Concept and Framework -> Operational Performance	0.141	0.086	1.637	0.051
Lean Tools and Techniques -> Integrative Mechanisms	-0.217	0.053	4.068	0.000
Lean Tools and Techniques -> Operational Performance	0.317	0.055	5.739	0.000

In the context of statistical analysis, mediation occurs when an intervening variable (mediator) accounts for the relationship between an independent variable (IV) and a dependent variable (DV). Specifically, the IV influences the mediator, which subsequently affects the DV, thereby elucidating the underlying mechanism or causal pathway through which the IV impacts the DV (Hair et al., 2014). The results presented in Table 4.5 provide empirical support for the hypothesized mediating effects. H8, which posits that the relationship between lean manufacturing concepts and frameworks and operational performance is mediated by integrative mechanisms, is supported ($\beta = -0.085$; $t = 2.809$; $p < 0.001$). Similarly, H9, which hypothesizes that the effect of lean tools and techniques on operational performance is mediated by integrative mechanisms, is confirmed ($\beta = 0.079$; $t = 3.341$; $p < 0.001$). Furthermore, H10, which asserts that the impact of lean activities on operational performance is mediated by integrative mechanisms, is also supported ($\beta = 0.100$; $t = 2.769$; $p < 0.001$). These findings highlight the crucial role of integrative mechanisms in facilitating the effectiveness of lean practices in enhancing operational performance, reinforcing their significance in lean management frameworks.

Table 4.5

Path Coefficients (Specific Indirect Effects)

	Original Sample (O)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Lean Activities -> Integrative Mechanisms -> Operational Performance	0.100	0.036	2.769	0.003
Lean Manufacturing Concept and Framework -> Integrative Mechanisms -> Operational Performance	-0.085	0.030	2.809	0.003
Lean Tools and Techniques -> Integrative Mechanisms -> Operational Performance	0.079	0.024	3.341	0.000

According to Hair et al. (2014), predictive relevance assesses the extent to which exogenous variables contribute to explaining endogenous variables, or how independent variables impact the dependent variable. This evaluation is conducted using the Q^2 criterion, which quantifies the model's predictive accuracy. Specifically, a Q^2 value of 0.02, 0.15, and 0.35 is interpreted as indicating small, medium, and large predictive relevance, respectively. The results of the predictive relevance assessment for this study are presented in Figure 4.4, demonstrating the explanatory power of the research model in capturing variance in the dependent variable.

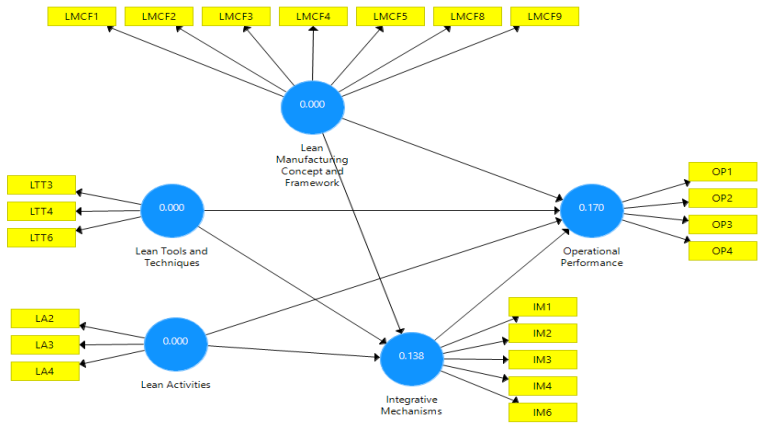

Figure 4.4 Predictive Relevance

5.0 DISCUSSIONS & CONCLUSION

Discussions

This study aims to rigorously assess the impact of Lean manufacturing concepts and frameworks, Lean tools and techniques, and Lean activities on the operational performance of semiconductor firms in Penang. Furthermore, the research seeks to evaluate the mediating role of integrative mechanisms in the causal relationship between Lean management practices and operational performance. To accomplish these research objectives, ten hypotheses were formulated and tested utilizing Partial Least Squares Structural Equation Modeling (PLS-SEM). The first set of seven hypotheses examines the direct effects of Lean manufacturing concepts and frameworks, Lean tools and techniques, and Lean activities on operational performance. In contrast, the second set of three hypotheses investigates the mediating influence of integrative mechanisms in shaping the relationship between the predictor variables (Lean practices) and the outcome variable (operational performance). The research findings as in Table 5.1 highlighted that all relationships in the first set of seven hypotheses examined in the analysis are supported, indicating significant associations between the variables studied. As for the other set of three hypotheses, all three mediated relationships examined in the analysis are supported, indicating significant associations between Lean manufacturing concepts and frameworks, Lean tools & techniques, and Lean activities mediated by integrative mechanisms on operational performance.

Table 5.1

Summary of Hypotheses Testing Resul

No of Hypothesis	Hypothesis Statement	Research Findings
H_1	Lean manufacturing concepts and frameworks exert a significant effect on operational performance	Supported
H_2	Lean tools and techniques exert a significant effect on operational performance	Supported
H_3	Lean activities exert a significant effect on operational performance	Supported
H_4	Lean manufacturing concepts and frameworks exert a significant effect on integrative mechanisms	Supported
H_5	Lean tools and techniques exert a significant effect on integrative mechanisms	Supported
H_6	Lean activities exert a significant effect on integrative mechanisms	Supported
H_7	Integrative mechanisms exert a significant effect on operational performance	Supported
H_8	Effect of Lean manufacturing concepts and frameworks on operational performance is mediated by integrative mechanisms	Supported
H_9	Effect of Lean tools and techniques on operational performance is mediated by integrative mechanisms	Supported
H_{10}	Effect of Lean activities on operational performance is mediated by integrative mechanisms is supported	Supported

Therefore, the research findings provide robust support for the hypothesized relationships between lean manufacturing practices and operational performance, as well as for the effect of integrative mechanisms as mediators in the stream of lean management practices and operational performance research. Hence, all hypotheses were supported, indicating a comprehensive validation of the current conceptual model. Based on the current findings, H1 which postulated that Lean manufacturing concepts and framework exert a significant effect on operational performance is supported. Therefore, research objective 1 has been achieved. Accordingly, the result has underscored the importance of adopting lean manufacturing concepts and frameworks. Lean principles, such as waste reduction, continuous improvement, and value stream mapping, evidently enhance operational performance. This finding aligns with existing literature, which emphasizes that streamlined processes and efficient resource management lead to higher productivity, better quality, and reduced costs.

Yet, the current findings have proven that H2, which postulated that Lean tools and techniques exert a significant effect on operational performance is statistically supported. Thus, research objective 2 has been achieved. Highlighting the critical role of specific lean tools and techniques, such as Just-in-Time (JIT), 5S, and Kanban, in improving operational performance. These tools facilitate a more efficient production process, minimize waste, and optimize workflow, leading to significant improvements in output quality and operational efficiency. Also, the statistical evidence implied that H3 which postulated that Lean activities exert a significant effect on operational performance is supported. Therefore, research objective 3 has been achieved. Demonstrating that the practical implementation of lean activities, including regular kaizen events and employee training, positively influences operational performance. Lean activities cultivate a culture of continuous improvement and active employee engagement, both of which are fundamental to achieving and sustaining long-term operational excellence.

Correspondingly, the current outcome showed that H4 which postulated that Lean manufacturing concepts and framework exert a significant effect on integrative mechanisms is supported. Testifying that research objective 4 has been achieved. Indicating that lean manufacturing frameworks not only improve operational performance directly but also emerge as an important driver of integrative mechanisms within an organization. Hence, lean principles promote better communication, coordination, and collaboration across different departments, which are essential for a cohesive and efficient operation. Equally, the statistical outcome showed that H5 which postulated that Lean tools and techniques exert a significant effect on integrative mechanisms is supported. Therefore, research objective 5 has been achieved. Showcasing that lean tools and techniques improve integrative mechanisms. Hence, tools such as value stream mapping and standardized work help semiconductor firms align various functions and processes, ensuring that different parts of the organization work together seamlessly towards common goals.

As well, the research findings supported H6 which says that Lean activities exert a significant effect on integrative mechanisms. Suggesting that research objective 6 has been achieved and highlighting that lean activities also strengthen integrative mechanisms. Hence, lean activities like cross-functional teams and regular improvement, and meetings breakdown silos, in totality foster an integrated approach to problem-solving and decision-making. Accordingly, the findings provided support for H7 which postulated that Integrative mechanisms exert a significant effect on operational performance. Suggesting that research objective 7 has been achieved, as the findings confirmed that integrative

mechanisms are crucial for operational performance. Hence, effective integration ensures that all parts of the organization are synchronized and work towards optimizing the overall performance, thus enhancing efficiency, quality, and responsiveness to market changes.

Furthermore, the empirical findings provided statistical validation for H8, H9, and H10, affirming that integrative mechanisms mediate the relationship between Lean manufacturing concepts and frameworks, Lean tools and techniques, and Lean activities with operational performance. Consequently, research objectives 8, 9, and 10 have been successfully achieved. This mediation effect underscores that the performance benefits derived from Lean concepts and frameworks are, at least partially, realized through their influence on strengthening integrative mechanisms within the organization. Similarly, the findings indicate that the impact of Lean tools and techniques on operational performance is enhanced when integrated with effective organizational mechanisms. Moreover, the results suggest that the effectiveness of Lean activities in improving operational performance is contingent upon the implementation of integrative mechanisms, reinforcing their critical role in facilitating Lean management practices.

Nevertheless, the comprehensive support for all hypotheses emphasizes the intertwined nature of lean management practices, operational performance, and integrative mechanisms. Lean manufacturing concepts and framework, lean tools and techniques, and lean activities, not only directly improve operational performance; but also, do so indirectly by fostering better integration within the organization. These findings reinforce the importance of a holistic approach to lean implementation, where both the technical tools and the integrative practices are given due attention. Therefore, organizations aiming to enhance their operational performance should focus on embedding lean principles deeply into their culture and processes, ensuring that integrative mechanisms are strengthened to fully leverage the benefits of lean manufacturing.

6.0 CONCLUSION

The robust contribution of this research is investigating the effect of a holistic model of lean management practices on operational performance, using integrative mechanisms as mediators, in the context of Semiconductor firms. Thus, the current findings have significant implications for both theory and practice in the field of lean management. These implications span several areas in promoting operational efficiency, the culture of productive maintenance to reduce wastages, detect defects, and prevent breakdown in the production process, as well as integration of organizational system through enhanced collaboration/teamwork among employees, and automation of production process, to provide better customer offerings. The findings imply that organizations should prioritize the adoption and implementation of lean manufacturing concepts and frameworks, tools and techniques, and activities, to sustain operational excellence. This prioritized the need for integrated mechanisms to ensure that lean principles are systematically embedded across all levels of the organization. Hence, firms can achieve substantial improvements in operational performance. Likewise, the positive effect of lean management practices on operational performance suggests that organizations can significantly enhance their level of efficiency and overall productivity, by adopting lean arrangements. This includes reducing waste, improving process flows, and increasing production. Correspondingly, lean tools like Just-in-Time (JIT) and Kanban can help organizations streamline their

operations, reduce lead times, and improve overall process efficiency. Accordingly, the confirmation that lean practices enhance integrative mechanisms highlights the importance of fostering coordination and collaboration across different departments and functions. Suggesting that organizations should focus on activities that promote cross-functional team integration to facilitate consistent communication and collaborative problem-solving. Hence, strengthened integrative mechanisms lead to a more cohesive and agile organization capable of responding quickly to market changes and internal challenges.

Another important implication of current findings is the application of system theory and RBV to support lean practices and integrative mechanisms in facilitating superior operational performance among firms in the Semiconductor industry. The support for lean activities impacting both operational performance and integrative mechanisms underscores the need for a cultural transformation within organizations, especially as lean manufacturing requires a culture of continuous improvement, employee engagement, and empowerment. Therefore, organizations should invest in programs that promote lean thinking and practices among all employees, and inspire a shift towards a culture that values efficiency, quality, and teamwork. Additionally, the mediation effect of integrative mechanisms on the relationship between lean management practices and operational performance, suggests that simply implementing lean frameworks, tools and activities is not enough. Hence, organizations must also focus on improving their integrative mechanisms, to fully realize the benefits of lean practices by fostering better communication, coordination, and alignment of goals and processes across all units/departments within the organization.

For managers, these findings provide a clear roadmap for implementing lean manufacturing. Managers should focus on:

1. Developing a comprehensive lean strategy that includes both the conceptual framework and practical tools.
2. Encouraging cross-functional collaboration and breaking down departmental silos.
3. Investing in programs that promote lean principles and practices.
4. Continuously monitoring and improving integrative mechanisms to ensure they support lean initiatives effectively.

For policymakers and decision-makers within organizations, the study suggests the need for policies that support lean initiatives. This includes resource allocation for lean projects, incentives for departments that successfully implement lean practices, and metrics to measure the impact of lean on operational performance and integrative mechanisms.

The study opens several avenues for future research. Researchers can explore:

i. The specific mechanisms through which lean practices enhance integrative mechanisms and operational performance.
ii. The long-term impact of lean manufacturing on organizational sustainability and competitive advantage.

iii. The role of technology in supporting lean initiatives, especially in the context of Industry 4.0 and digital transformation.
iv. Comparative studies across different industries and regions to understand the contextual factors that influence the effectiveness of lean practices.

Therefore, the implications of these findings are profound for both practitioners and researchers. For practitioners, the study provides actionable insights into how lean practices can be leveraged to improve operational performance and foster integrative mechanisms within organizations. For researchers, the study highlights the need for further investigation into the complex relationships between lean practices, integrative mechanisms, and operational outcomes. Ultimately, embracing lean principles can lead to a more efficient, responsive, and competitive organization.

7.0 ACKNOWLEDGMENT

This research did not receive any specific grant from public, commercial, or not-for-profit funding agencies.

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