INFLUENCE OF SUPPLIER INTEGRATION, HUMAN AND TECHNICAL LEAN PRACTICES ON OPERATIONAL PERFORMANCE OF SEMICONDUCTOR INDUSTRY: KNOWLEDGE BASE ENGINEERING AS A MEDIATOR AND TECHNOLOGICAL TURBULENCE AS A MODERATOR

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LIST OF ABBREVIATIONS

LM	Lean Manufacturing
HLP	Human Lean Practice
TLP	Technical Lean Practice
SI	Supplier Integration
KBE	Knowledge Base Engineering
TT	Technological Turbulence
RDT	Resource Dependent Theory
KB	Knowledge Base Theory
CI	Contingency Theory
OP	Operational Performance
JIT	Just In Time
VSM	Value Steam Mapping
TPM	Total Productive Maintenance

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PENGARUHAN INTEGRASI PEMBEKAL, AMALAN LEAN SUMBER MANUSIA DAN TEKNIKAL TERHADAP PRESTASI OPERASI DALAM KALANGAN INDUSTRI SEMIKONDUKTOR: KEJURUTERAAN BERASAS PENGETAHUAN SEBAGAI PENGANTARA DAN PERGOLAKAN TEKNOLOGI SEBAGAI PENYEDERHANA

ABSTRAK

Firma pengeluar semikonduktor yang teguh beroperasi di negara membangun tidak terlepas daripada persaingan sengit yang mengakibatkan kesan penutupan kilang. Justeru, kajian ini direka dan dibangunkan untuk memahami amalan pembuatan lean secara menyeluruh yang merangkumi amalan lean manusia, amalan lean teknikal, integrasi pembekal, kesan mediasi kejuruteraan berasakan pengetahuan dan kesan moderasi perolakan teknologi yang mengpengaruhi metrik prestasi operasi berasaskan nilai kewanagan dan bukan kewangan di dalam industri semikonduktor Malaysia. Firma pengeluaran semikonduktor merupakan industri yang mencabar dari segi kos pelaburan, kos operasi, permintaan pelanggan yang semakin berubah dan jangka hayat produk yang pendek. Hasil kajian ini bertujuan untuk menambah dan meluaskan pemahaman pengetahuan yang mendalam terhadap factor-faktor yang boleh menpengaruhi prestasi operasi di negara membangun. Penggunaan teori berasaskan pengetahuan sebagai teori utama kajian membolehkan pemahaman terhadap kepentingan pengurusan aset pengetahuan sebagai faktor penting dalam kelangsungan firma. Kajian ini meluaskan skop model penyelidikan dengan penggunaan pembolehubah kejuteraan berasaskan pengetahuan menggunakan teori berasaskan pengetahuan dan perolakan teknologi berdasarkan teori kontinjensi yang memberikan pengaruh terhadap prestasi kilang. Hasil kajian ini merangkumi data daripada 149

firma yang memberi maklum balas dari populasi firma semikonduktor yang beroperasi di Malaysia. Perisian SmartPLS dan SPSS digunakan dalam memproses dan menganalisis data maklum balas dari proses pengumpulan data sepanjang tempoh empat bulan. Sepuluh hipotesis dibina untuk kajian ini dan hasil analisis menunjukkan lapan hipotesis disokong, justeru mengesahkan bahawa amalan lean manusia, amalan lean teknikal, integrasi pembekal serta kejuruteraan berasaskan pengetahuan mempengaruhi prestasi operasi firma secara positif manakala perolakan teknologi menpengaruhi amalan lean manusia dan amalan lean teknikal secara negatif. Pemahaman terhadap pengaruh kejuruteraan berasaskan pengetahuan membolehkan firma pengeluar meningkatkan pengunaan asset pengetahuan untuk penyelesaian masalah serta meluaskan asset pengetahuan dicapai serta diguna semula untuk meningkatkan keupayaan penyelesaian masalah sebagai pemacuan peningkatan prestasi operasi. Secara tidak langsung, kaedah ini meningkatkan kemampuan pekerja untuk menyerap dan memindah pengetahuan yang dapat membantu firma ke arah peningkatan produktiviti, pengurangan kos berlebihan serta meningkatkan fleksibiliti proses. Kajian ini juga menambah pemahaman terhadap faktor luaran firma untuk kepentingan positif prestasi operasi dengan menggunakan integrasi pembekal yang berupaya berfungsi sebagai saluran untuk firma mencapai sumber kritikal yang tidak sedia ada dalam aset pengetahuan firma. Penggunnaan teori kontinjensi untuk pemahaman perolakan teknologi dalam kajian ini memberikan model kajian yang realistik, ini adalah penting untuk memahami faktor-faktor yang mempengaruhi prestasi operasi firma secara keseluruhan, terutamanya dalam industri semikonduktor.

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ABSTRACT

Semiconductor firm in developing countries face intense competition resulted occurrence of factory closure and relocation despite well established. Hence, this research was designed and developed to understand holistic lean manufacturing practices that breakdown into human lean practice, technical lean practice and supplier integration toward financial and non-financial operational performance metrics in Malaysia's semiconductor industries. The contribution of the research objective enables future researchers to gain comprehension of various variables relevant to operational performance in developing countries. This research adds to the novelty with the introduction of knowledge base engineering and technological turbulence in the model allowing for a robust understanding of factors that can affect firm operational performance. This research was conducted with 149 valid responses from 237 firms in the semiconductor industry population of Malaysia, where the semiconductor industry is one of the industries with high technology dynamics, a short product life cycle, high expenditure, and yet high demand. The collected data were processed and analysed using SPSS and SmartPLS software. A total of eight hypotheses are supported out of ten developed hypotheses, confirming that human lean practice, technical lean practice, supplier integration, and the mediating effect of

knowledge base engineering are positively affecting firm operational performance while technological turbulence is negatively moderating the practice of human and technical lean practice toward firm operational performance. The establishment of the relationship between variables allows further understanding of knowledge usage in resolving problems and make it accessible for reuse in the future as part of problem-solving ability in respective processes and systems, which also indirectly reflect the firm's employee capability to absorb and use knowledge to drive performance. Firm progress is not only strengthened through internal optimization but can be enhance with the external integration, hence resource dependence theory is used to understand the criticalness of exchanging with an external firm to acquire resources not available internally from a supplier. Knowledge base theory stress the need for organisations to create and manage knowledge to enable firm exploitation toward sustaining competitive performance. In order to give a realistic model, it is crucial to understand factors that affect firm performance externally, especially in the semiconductor industry, where the dynamic change of technology competitiveness. The use of contingency theory to explain the role of technological turbulence toward firm performance. Technological turbulence was studied and revealed that the increase of interaction with human lean practice and technical lean practice resulted in lower operational performance.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter provides the background of a study in operational performance measurement metrics, the application of lean manufacturing practice, knowledge base engineering, *external* partnership with supplier and technological turbulence's influence toward the performance of semiconductor factory in Malaysia. The next proceeding section discussed the background of the global value chain of the semiconductor manufacturing industry and its footprint contribution in Malaysia, including the challenges currently facing by semiconductor factories. The following section continue with the discussion of the problem statement, research gap, research objectives, research question, research significance and appropriate definitions of important concepts used in the research.

1.2 Background of Study

The environment of the semiconductor industry is a very globalized, with no known boundaries where the value chain spans across the globe driving the dynamic propulsion for technological advancements in many forms such as the development and introduction of autonomous vehicles, wireless communication, and artificial intelligence (Grimes & Du, 2018). Semiconductor product life cycles are typically short (Vayvay & Cruz-Cunha, 2016) and require high expenditures in new research and development to sustain growth and implementation at the operational level for mass manufacturing (Lee et al., 2017, Jo et al., 2019). The environment for semiconductor is one of the most difficult platforms to implement manufacturing

productivity efforts in the manufacturing system due to high capital costs of production assets, complexity of equipment, and variable user-configurable processing options (Pormoski, 2010). Historically, based on Moore's Law, the semiconductor industry doubles the performance per cost of devices every one year and later decreases to eighteen months, but it is still influencing the competition among the manufacturers (Randall et al., 2018). The complexity of the manufacturing firm in managing its development, ramp up operation and meeting customer delivery cycle time required high focus in flexibility but yet it needs the balance between competing for market share and being profitable contributes to how firms need to manage both its internal performance and its operational performance (Dombrowski et al., 2018).

The global value chain is a complex environment with a multi-industry segment in the fabrication of semiconductors from delivery to end consumers in assembled products with lucrative financial returns (Pormoski, 2010). The value chain of semiconductors is comprised of an integrated device manufacturer, outsources semiconductor assembly and test, fabless, foundries, and equipment manufacturers of semiconductors, which contributed to the turnover of USD 440 in 2018 worldwide and climbing to reach USD503 billion in the year 2020 with a 51.7% share of the industry revenue that is mainly dominated by US companies with 51% share, South Korea with 28%, Europe with 11%, Taiwan with 7%, and China with 2%, while a fraction of the other smaller countries where Malaysia are located in the other country with plenty of opportunity to expand (Grimes & Du, 2018). The rise of technology from industry to end consumer gadgets consists of a multi-array of semiconductor products use inside smartphones, computers, car driving assist or an autonomous vehicle, aviation and any electronic products (Jo et al., 2020). The semiconductor footprint started by Infineon started in 1973 in Malaysia, through its Melaka plant where it serves as the only

location beyond developed country of manufacturing in USA and Europe that include production of wafer products from scratch at fabrication level and as well as assembled products in semiconductor operation for the back end operation (Malaysian Investment Development Authority: The Semiconductor Industry: Moving Up the Value Chain, 2020). However, the gap still big and there are big opportunities for Malaysia to fill in the semiconductor market as Malaysia is part fraction of 1% that shared by many emerging countries as research by Grimes & Du (2020). The emergence of competition in Vietnam and Thailand semiconductor industry resulted in increase of investment in Thailand in 2020 with the semiconductor market was USD 1.5 billion and Vietnam semiconductors market investment of USD 1.65 billion in 2020 ("How ASEAN Can Move Up the Manufacturing Value Chain", 2022). This reflect rise of competition between developed economy in ASEAN region to compete for the market footprint where Malaysia used to play a big role as destination for semiconductor technology investment. The setup of semiconductor factory footprint in Thailand and Vietnam reflect the ability of the workforce to effectively absorb the transferred technology and demonstrate the ability to meet required performance measurement (Sultana & Turkina, 2020) while Malaysia has taken a more relaxed approach in its manufacturing expansion than neighboring countries (Haseeb et al., 2019).

Post covid 19 pandemic recoveries in customer demand had resulted manufacturing firm facing situation of running into manufacturing bottleneck as the industries operation are picking up resulting many factories are now running at max capacity and any further increase in short time frame is not possible ("Chip Shortage 2021: 7 Companies Feeling the Heat From Global Semiconductor Demand", 2021). Factory in general such as in semiconductor industry is operating in high volatile and high fluctuation industry (Jo et al., 2019, Cho ,2020) with high capital cost of

production assets, complexity of equipment and various customer configurable processing options resulted as much as 80% of that cost being the purchase and installation of production equipment (Pormoski 2010, Randall et al., 2018). This research are design and develop as attempt to filling the gap and offer the industrial practioner a better understanding of the crucial factors toward improve the factory operational performance.

The challenge of competition in the business environment had moved beyond the individual firm in a localised area to the global scene with multiple competitors plying the same trade segment without boundary and pushed the market to be effective and efficient (Möldner et al., 2020). As business competition becomes more intense in the current era of globalization, it becomes more important that organization focus on efforts to identify, measure, comprehend and efficiently manage the performance of the factory (Villazón et al., 2020). The appropriate setup of effective measurements inclusive of the foundation of structure performance measurement systems which reflect the monitoring and allow maintaining organizational control of ensuring that organization aims at strategies that lead to the achievement of its overall goals and objectives (Liker, 2004). The use of appropriate performance measures, play a vital role in and often view as indicators that provide reflection of the actual status of company performance reveal the need for possible changes in operations (Rasi et al., 2015). The choice of performance measure is one of the most critical challenges face by organization to make the right choice to reduce the uncertainty to achieve expected performance (Orji & Liu, 2020) as poorly chosen performance measures routinely create the wrong signals for managers, leading to poor decisions and undesirable results, where wrongly chosen performance measures, which in turn push management to take improper decisions (Haseeb et al.,2019).

Overall performance and profitability can be achieved by improving the manufacturing system through effective changes to the element of manufacturing system design, also known as manufacturing system productivity, can result in the entire production system and drive advanced asset-intensive manufacturing operations to be more effective (Möldner, et al., 2020). Many research had been established to examine the relationships between various manufacturing systems and the impact of such practices on financial performance (Song et al., 2017), however research that focuses on the use of operational performance measures to assess how a factory level is performing in financial and non-financial aspects is rarely explored as the interest in prior research focuses more on the financial performance of a firm in business performance in developed countries as they view financial performance as the bottom line for business profitability (Trattner et al., 2019). The purpose of this study is to gain an understanding of the holistic factors that influence the improvement of operational performance measurements in factories located in Malaysia as a developing country in order to achieve improvement in financial and non-financial criteria of operational performance covering variables from the external influence of technological turbulence, which is something that was lacking in the prior studies.

The use of lean manufacturing practice as manufacturing system productivity improvement practice had been focal point to improve operational performance in specific areas such as delivery, quality, cost and flexibility (Rasi et al., 2015), however there are many that produce inconsistent result which cost a hefty investment (Ng & Ghobakhloo, 2018). The use of various manufacturing systems such as lean manufacturing have been widely implemented in the factories driven by various advantage such as contribution in high level automation, low cost approach and result in higher quality conformance that is also to influence result in overall line

manufacturing efficiency for mass production (Wang et al., 2022). The progressive evolution of lean manufacturing (Hines et al., 2014) contribute the increase complexity of factor that drive success in lean manufacturing practice toward operational performance (Hardcopf et al., 2021). However, to make it applicable and fit in every manufacturing to be successful is difficult influence by various factors including volume, product differentiation and diversity in manufacturing process which need a better understanding of the influencing factors (Haseeb et al.,2019). A more compressive understanding of the practice is needed to understand the contribution of lean manufacturing dimension in further understanding of socio technical approaches (Möldner et al., 2020) in support of improve operational performance where many focus on either socio (Almanei et al., 2017, Alefari et al., 2017, Ngadiman et al., 2019) or technical (Lamani et al., 2020, Nawawi et al., 2019) toward line improvement despite lean manufacturing is a holistic approach which had been stress by in work by Liker (2004) but not many had proceed to go further.

Manufacturing system application in current competitive environment required much more effort beyond the optimization of internal factory processes and infrastructures in single process by process as the complex network composed of many factors internally (Li et al., 2022) as well as externally which includes strategic partnership in interaction with supplier to acquired needed resources (Khalil, et al., 2019). External lean integration at supplier plays important role for successful internal lean manufacturing practice (Liker, 2004) especially in semiconductor manufacturing as the reliance on supplier for technological in the complex value chain to supply can collaboration to deliver customer required feature (Jo et al., 2019). Optimizing the exchange of information through communication with suppliers act as resource harvesting that is beneficial to the internal manufacturing system advantage (Schuh et

al., 2016). Hence, the research includes the understanding of interaction with external with supplier integration (Khalil et al., 2019). The use of underpinning theory of resource dependence explains how organizations exploit environmental interdependence and external resources for internal needs (Pfeffer & Salancik, 1978) where the theory implies the firm survival and making decision is relying on dependencies in external environment (Hillman et al., 2009). Firm need to obtain needed information to make the right decision or to strengthen performance thru the increase of internal knowledge asset (Goyal, et al., 2020), and one way is to focus on supplier specific relationship with the early engagement to develop trust and understanding product development process which support the reduction of development time of new product to mass production (Zhou & Li, 2020). Interorganizational relationship for supplier integration enhance the dealing capability with external party to obtain crucial resources in physical and intangible resources to enhance problem solving capability and decision-making process (Song et al., 2017).

The ability of organization to grow and maintain competitiveness and sustainable growth required the organization to collectively use knowledge asset continuously to create new knowledge and pursue practical wisdom that can be use as organization advantage (Nonaka et al., 2014). In the highly challenging technological driven environment for semiconductor, dynamic capabilities to embark on knowledge creation enables the company to mitigate the challenging condition toward success and continuity of innovations in a collaborative method toward improved firm performance (Elidjen et al., 2022). As firm progress and solve problem day in and day out, it is eventually growing and create knowledge where it is defined and use explicitly in research as justified true beliefs and bodily acquired skills (Nonaka ,1995) which uses to solve problem or act on to improve business situation (Kane et al., 2016).

Manufacturing firm survive with the use of knowledge from engineers, technicians, operators and supervisors regardless of product design to solve day to day issue in manufacturing internally of the firm (Lovett et al., 2000 and as well as acquiring from external (Schuh et al. 2016) which translate to the criticalness to understand the influence of knowledge toward the actual firm performance. The implementation of "lean manufacturing and its tool is actually a process of knowledge creation, transformation, storage, and application of knowledge" (Zhang et al., 2018) had become the focal point for this study in attempt to understand and explain the influence knowledge apply in lean manufacturing practices toward the firm increase performance. The use of knowledge to solve problem and make it accessible for reuse in future is part of problem solving ability in respective processes and system (S.Thomke & Fujimoto, 2000) as the use and application of knowledge management effective enhancement toward production and drive organizational growth thru adequate manage of organization knowledge creation, sharing and use of information (Thomas, 2021). Hence, the ability of a firm in developing its core competency in the management of internal knowledge in storage and apply in solving organization challenges is part the recommendation from knowledge base theory where firm exist due to the ability to manage and acquire knowledge (Miles, 2012) which also include obtaining from externally to enable firm exploitation toward sustaining of firm competitive performance (Goyal et al., 2020). Knowledge base theory suggests that the ability to manage and apply knowledge for survival indirectly translates to an employee's capacity to absorb and utilise knowledge to drive performance and collectively manage and store allow the vast knowledge to be use toward the form advantage (Sultana & Turkina, 2020). Firm need to reflect and understand the use of knowledge which include engineering knowledge to solve day to day issue supporting

various employee to be productive, hence the use of knowledge base engineering are able to provide the required support in reuse and exploitation of knowledge within the firm (Quintana-Amate et al., 2017).

Despite success in the firm lean manufacturing implementation resulting in firm performance increase, it may not be consistent and replicate effectively in other firm and industry as external influence of industry conditions is seen playing a big part in affecting the relationship between competition in the market toward firm internal performance which include the change in technology (Likitwongkajon & Vithessonthi, 2022). Firm are operating in open systems that need careful management to satisfy and balance internal needs toward environmental circumstances as there is no universal way of organizing that is considered to be the best where the appropriate form depends on the kind of task or environment one is dealing with and understanding the impact toward firm strategy (Donaldson, 2001). The impact of technology is higher in firm operating in semiconductor industry due to the dynamic situation from competitor in affecting on how a firm progress and compete as amount of change that has occurred in semiconductor wafer since the early days of Moore's Law may give industry players economy of scale, but there is also a concern that it may force factories to become obsolete and unable to compete with other businesses (Randall et al. 2018, Jo et al, 2019). As the competitive environment in the high technology industry becomes more volatile, resulting in unforeseen technical developments, the internal structure of firm is affected as employees are required to adapt and operate outside of their comfort zone in both exploitative and explorative knowledge creation jobs at the same time to cope with the transition (Folger et al., 2021). During this intensity of technology change, firm may run into indecisive decision to embark on new knowledge, adaptation and exploitation lead to the firm underperforming, hence inadequate to provide product

offering with the latest requirement of lack of conformity to customer expectation in speed, quality and alterations (Jin et al.,2022). Technological turbulence causes uncertainty environment that may result in competitive advantages that keep the organization profitable becoming negative as the firm knowledge asset become deteriorate and progressively obsolete (Elidjen et al., 2022). Technological turbulence had been defined as the rate of technological change over time within an industry which arises from fast technological change in products and breakthroughs in manufacturing processes (Chavez et al., 2015). Firms in developing technologies are subject to high technological turbulence, where it is defined as the degree of volatility, change, and unpredictability related to rapid change (Calantone et al., 2003). The use of contingency theory in this research implies that there is no single best method of managing firm as contingency theory argues that there is no universal set of strategies that able to cover all business decision and external impact where a firm can excel if the correct strategy is used (Donaldson, 2001). The fast pace technology in the market may outpace the firm capability to compete and result is disadvantage to the factory (Chavez et al., 2015).

In the contextual circumstances of the research in semiconductor industry in Malaysia will allow practioner to understand impact of high technology turnover from Moore's Law effect with use of lean manufacturing, supplier integration and knowledge base engineering toward affecting changes in operational performance. The environment of developing country of Malaysia and factors affecting the performance are likely to be different compared to the past research that were based on practices implemented by successful large firms in Germany, Japan and the USA as cultural differences may contribute to fundamentally different manufacturing strategies (Karim et al., 2008). It is noteworthy that this research would help industry practitioner to

understand what work and what do not work at magnitude toward operational performance and how severe is technological turbulence impact to firm operational capability.

1.3 Problem Statement

Factories of well-established industry major does not escape closure and relocation when underperform in achieving profitability to the overall business model (Costa et al., 2019). Despite Malaysia being part of Southeast Asia is a prime candidate for new competitive factory locations, the recent emergence of competition in Vietnam and Thailand semiconductor industry result in change of ecosystems. Thailand had recorded investment of USD 1.5 billion and Vietnam with USD 1.65 billion in 2020 result in change of ecosystem of semiconductor manufacturing footprint ("How ASEAN Can Move Up the Manufacturing Value Chain", 2022). Seagate closes two of its manufacturing facilities in Penang and Negeri Sembilan in 2016 from corporate restructuring exercise to reduce cost structure on low operational performance site and relocated to Korat Thailand which uses less manufacturing space and ability to produce higher technology-oriented product and not due to weak demand ("Seagate Shuts Down Malaysian Plant Amid Internal Consolidation Drive", 2022). On the other hand Fairchild had closed the factory in Malaysia as well as part of Fairchild's ongoing initiative to enhance manufacturing operational capabilities, improve product quality, and lower costs resulting in greater supply chain flexibility and responsiveness to their customers in location beyond Malaysia which are able to contribute in better operational performance financially where the site beyond Malaysia demonstrated the ability to flex capacity with much faster cycle time , significant cost reduction and quality improvement as well ("Fairchild Semiconductor to close two facilities, cutting 15% of workforce | Semiconductor Digest", 2022). The manufacturing industry in

Malaysia is facing challenges in the manufacturing sector with in managing operational performance to improve competitiveness, quality and delivery topic to move up the value chain in keeping up with development and manufacturing capability to increase product quality and improving productivity (Karim et al., 2008). Many factories used the term corporate restructuring (Costa et al., 2019) but few like Fairchild and Seagate which stated the reason of shift to other site that is more competitive in operation and technologically capable site.

Various aspects can greatly affect the desire business performance in both internal and external of a firm (Costa et al., 2019). The changes in performance should be measure as accurate as possible to allow the correct signal send to the management for correct decision to be make (Henao et al., 2019). Operational performance should be measure holistically to ensure that what is intended is measured to achieve overall outcome of factory performance strategy (Khalil, et al., 2019). Research by Chavez et al. (2015) revealed that many of the research tend to focus on the financial oriented performance but not in holistic approach in both financial and non-financial that include delivery and flexibility. Financial performance is given more weight in past research as they view financial performance as bottom line for business profitability (Trattner et al., 2019) which result in incomplete signal to the management due the absent of non-financial like delivery, flexibility and quality criteria (Ahmad & Zabri, 2016). The advantage of ensuring right fit of measurement in operational performance reflect transparency (Grimsley, 2015), structuring of resource to act in order to achieve responsiveness to external market (Song et al., 2017).

The suitability to apply various manufacturing systems such as lean manufacturing offer many advantages such as contribution in high-level automation, low cost approach and result in higher quality conformance (Wang et al., 2022) but to

enable fit into every manufacturing setup to be successful is difficult due to unique requirement between organization to organization (Haseeb et al.,2019). Manufacturing system is a knowledge-driven system that required both personnel and technical methodology to deliver required result where the absent of the factor may explain some previous research that did not establish relationship between lean manufacturing system and operational performance (Ng & Ghobakhloo, 2018) as knowledge in its capacity is used to define a situation and act accordingly where knowledge is oriented towards defining and solve problem (Kane et al., 2016). The research by Rasi et.al. (2015) stated that many organizations had begun to focus and encourage the use of lean manufacturing in developing economy such as in Malaysia's factory as a mechanism to improve manufacturing practice however in reality there are many that failed (Ng & Ghobakhloo, 2018, Costa et al., 2019) which is a good starting point to understand various factors that may sway the outcome of operational performance empirically. Many firms implement changes to manufacturing system to improve performance with lack of understanding of the system holistically which adopted from other countries in various economic setting result in association of lean manufacturing toward improvement unsuccessful (Wyrwicka et al., 2017). Research to understand contribution in lean manufacturing revealed that some firm practice lean manufacturing inadequately equips employees with appropriate knowledge (Rathilall & Singh, 2018) which may lead to potential barrier to implementation as a result of insecurity to change with having the right knowledge that may affect outcome to the expected performance measurement (Iranmanesh et al., 2019). The understanding of key factors that actually drive the improvement manufacturing system whether is socio or technical aspect allow factory to focus and not oversight of critical of any critical factors (Haseeb et al.,2019, Battesini et al., 2021). In the context of the research

environment in semiconductor factory highly asset-intensive manufacturing operations (Pormoski, 2010) where successful implementation of manufacturing practice result contributed to the company survivability and failure would lead to catastrophic outcome (Turesky & Connell, 2010).

The many past research that had been done prior had established the association between lean manufacturing practice with operational performances (Mohammed Iqbal, R., 2011) but it run short of explaining the causal of the relationship which the ability of the organization uses knowledge from the manufacturing practice to solve problem in manufacturing line as use of lean manufacturing practice lean knowledge creation and ability to apply to the operation according to Zhang et al., (2018). The relationship between manufacturing practice influence toward operational performance has been studied previously which include the use of lean manufacturing toward various measures of operational performance (Hardcopf et al., 2021) however the understanding of how lean manufacturing is actually contributing from the perspective of managing and reusing knowledge is never attempt despite, Zhang et al., (2018) stress that the implementation of lean manufacturing practice and its tool is actually a process of knowledge creation, transformation, storage, and application of knowledge. Prior researches recommended that firm manage and expand their own knowledge asset in pursuing problem solving capability with innovation with using organization learning theory (Mathews, 2017), the absorptive capacity theory (Liu & Woywode, 2013), knowledge-based view (Kotcharin et al, 2012) but stop short on focus on ensuring the acquired resource is well manage, codified and reuse efficiently internally to reduce the uncertainty and highly reliance external resources (Duan et al., 2022). Knowledge base theory is use as the main theory in this research which implies that organizations existence is contributed from the capability to make use of

knowledge effectively and efficiently that include the management of internal knowledge in storage and apply in solving organization challenges (Miles, 2012). The use of knowledge to solve problem and make it accessible for reuse in future is part of crucial activities to grow the problem-solving capability in respective processes and system (S. Thomke and Fujimoto, 2000). The gap in prior research may reflect the weakness in applying lean manufacturing and obtaining positive operational performance consistently due to the lack of focus in the creation, managing and reuse of knowledge as imply by knowledge base theory likely resulted that some authors find that only certain lean manufacturing tool and practices positively influence operational performance (T Adesta & Probowo, 2019). This is further elaborated from, Quintana-Amate, et al., (2017) that many firms lack practice of employee knowledge retention resulted in many knowledge stay within localized are of the firm or leaving the firm when the employee leave the firm, hence firm repeating knowledge creation redundancy.

Problem solving in organization contribute to creation of products and service when allow to be recycle lead to more knowledge creation capability by solving complex issue where the higher the challenge of the issue lead to generation knowledge to maintain competitiveness and sustainable growth (Nonaka et al., 2014, Victer, 2020). Knowledge created from lean manufacturing is pivotal within organization and reuse repetitively from multiple individuals in the organization (Tyagi et al, 2015) in solving problem is highly needed to reduce redundant routine, however lack of systematic management of the knowledge lead to redundant knowledge creation and resource allocation (Quintana-Amate et al., 2017). Firm that seeks continuous growth in defining and allowing reuse of knowledge tend increase employee alignment toward responsiveness toward competition relate knowledge management as an effective

approach (Thomas, 2021). Responsiveness from employee drive improvement in delivery commit (Trattner et al., 2019, increase flexibility toward customer request (Yu et al., 2015) and indirectly draw conformance (Wong et al., 2011) which reflect the critical measurement of financial and non-financial performance of operational performance that is crucial to the manufacturing firm performance (Ahmad & Zabri, 2016). Despite the stress of important of knowledge Stenholm (2019), prior research short of addressing the reuse and automate knowledge application efficiently. The intense competition in technology driven sector (Ramona & Alexandra, 2019) translated to more efficient use of knowledge is crucial in diverse multi discipline collaboration as the use in knowledge base engineering to reduce redundancy (Quintana-Amate et al., 2017), thus the gap open to understand the use of knowledge base engineering as mediator beyond the mediation role of knowledge management. Despite some prior research stress on the critical use of knowledge in manufacturing is part of organizational knowledge creation that link toward firm performance from activity in retaining and codified of knowledge for continuous usage (Pinheiro et al., 2020), there is one more aspect to focus which technology that is playing a big role influence the dynamic change from the external environment (Likitwongkajon & Vithessonthi, 2022). Firm need to act to the market dynamic to understand and focus of managing of knowledge in enables the company move toward improved firm performance (Elidjen et al., 2022) where this exert pressure to understand the role of knowledge and new approach to increase operational performance in financial and non-financial such as use of knowledge base engineering that move beyond management to automation of redundant activity in reacting to the external influence of technology change.

Firm ability to progress base on effective use of knowledge is not limited to the use of internal knowledge asset but rather include external knowledge as form of compliment and support to the firm use of and manage of knowledge efficient and effectively. The ability to negotiate and exchange with environment describe how organisations decrease environmental reliance and unpredictability with the use of resource dependence theory (Hillman et al., 2009). Resource dependence theory discuss and propose that organizations rely upon external parties to garner resources critical to their operational and be in existence in open environment when internally generate required resources are seen as insufficient to maintain themselves. Resource dependence theory had presented unique ways to explaining organisational decisions, crucial aspect of organisations is survival. is highly contributed by the firm capability to obtain needed resources at point of time of need from external environment which is propose by resource dependence theory (Pfeffer, 1972). Strategic partnership is outlined as an important motivation in the integration of suppliers using strategic planning and operational information, as well as creating financial linkages that lead to dependency upon mutual performance (Khalil et al., 2019), where firm operate in an open environment where its survival and firm decision or behaviour is relying on dependencies in external environment, in such it explained a firm is always looking at opportunities of resources to be exploit to its advantage (Hillman et al., 2009). Firms in this situation are required to be interacting with the environment to fulfil their interests to enter into relationships with suppliers to obtain the much-needed resources, and also explain the ability to reduce uncertainty from available information (Zhou et al., 2020). The negotiation with environment entities required interorganizational effort that firm seek to address the deficiency from partnering in symbiotic approach and horizontal approach and consider structurally equivalent that independence

complement each other as viable transactional partners (Chen et al., 2018). In semiconductor industry, the access to intangible resources is a key driver to support existing knowledge creation (Cho, 2020) which drive the need collaboration in symbiotic and horizontal relationship between which bring benefits to the respective firm (Vafaei-Zadeh, et al., 2020). The approach of supplier integration in early involvement is crucial in semiconductor manufacturing where information sharing practice contributed to factory growth where factory can embark on external exploitation of information from supplier (Jo et al., 2019, Chatha & Jalil, 2022). Despite the benefit demonstrated the association supplier integration approach toward firm is more focus on financial performance (Naway & Rahmat 2019) but firm need both tangible and intangible resource in position to compete and be in existence (Shou et al., 2018). External source of intangible data in the form of data, information, and knowledge result in enhancing the internal knowledge creation and reuse (Song et al., 2017, Zhou et al., 2020) and one way to access is the approach of supplier integration but yet not many research had taken further to understand especially in semiconductor manufacturing.

The inconsistent association of various research in which do not find support of supplier integration toward the improvement of operational performance (Shou et al., 2018) while other shown positive outcome in performance result from supplier integration which lead to access of critical information which compliment internal lean manufacturing practice (Khalil et al., 2019), similar observation from past research on association lean manufacturing practice toward firm performance (Ng & Ghobakhloo, 2018, Costa et al., 2019). This uncertainty of result was hypothesized to be impacted by complexity but what drive complexity yet to be explore from the literature review where much of complexity is driven by competitor technological offering and

customer technology requirement changes (Siriram et al., 2022), which mean one way we can infer that the external environment turbulence in technological turbulence play a role in influencing the internal change and capability to compete effectively (Chavev et al., 2015). Contingency theory propose that a firm need to find and understand the fit between its organizational setup and environmental influence that fluctuate as in the event is misfit it will impact the performance in business, operational and result in detrimental on organizational performance (Lucianetti et al., 2018). The fitting characteristic to the organization in interaction with environment to achieve desire outcome of performance (Burn & Stalker 1961) where the effect of independent variable X to dependent variable Y is influence by another variable Z from the external of the organization where it can influence the misfit of X to Y where the organization need to take steps to address the shortcoming or challenges cause by Z in order to achieve a fit in the situation (Donaldson, 2001). External influence of industry conditions is seen playing a big part in affecting the relationship between competition in the market toward firm internal performance which include power of competition that influence the change in technology (Likitwongkajon & Vithessonthi, 2022). Indirectly the external influence are seen as negatively impacting the firm despite argument by Möldner, et al., (2020) that the influence of technology may increase innovation capability of a firm that will enable a firm to achieve higher performance, however this subject on the firm internal capability to match the misfit as the environment (Li et al., 2019). External influences are seen to affect the factory internal performance in creation of knowledge to solve high complexity problem and contribute to the factory ability to develop and use cognitive capabilities (Victer, 2020). While the attempt to use contingency theory is not new in the lean manufacturing and business performance (Chavez et al.,2015) but to explain from

external influence of technological turbulence influence is yet to be approach in a holistic approach that breakdown lean manufacturing practices with managing of knowledge effectively toward factory operational performance in financial and non-financial performance to reflect the capability of the factory to achieve is targeted goal. By further fill in the gap to understand the impact of technology turbulence toward a firm performance (Calantone et al., 2003), where this may allow the firm to understand better in the structuring resource to the external needs (Haseeb et al., 2019). In prior research the gap remains open as to understand the influence of technological turbulence to the firm, it is not a doubt that technological change can simulate the innovation capability (Möldner, et al., 2020), but in reality, there is no guarantee that the organization can remain unchallenged (Victer, 2020) as there are only a small fraction are able to cope with state-of-the-art technologies to be market leader (Calantone et.al, 2013). Firm operational performance are likely to be impacted as increase in technological turbulence, supplier and firm are likely to adopt measure to protect the technology to prevent technology leaks where it leads to firm unavailability to get access to the critical resources (Jin et al, 2022), increasing its inventory stock with more supplier (Chatha & Jalil, 2022), employees were subject to acting beyond comfort zone in both exploitative and explorative knowledge creation tasks simultaneously to cope with the change (Folger et al., 2021) and firm subject to new knowledge asset creation to stay competitive (Elidjen et al., 2022).

Various research had been conducted to understand the impact of lean manufacturing in productivity, yield and cost toward lean manufacturing performance but limited research that attempt to understand the breakdown lean manufacturing pillars towards operational performance in semiconductor factories (T. Adesta & Prabowo, 2019 Nawawi et al., 2019). Based on 145 papers related to productivity, lean

manufacturing, socio-technical, operational performance, and lean supply chain spanning 2010 to 2020, it was identified that 16 papers are related to semiconductor factories in the operational topic. A further breakdown to identify the country sample of the study reveals that 15 papers are carried out in the United States of America and Korea, while 1 paper is research on semiconductor factories in Malaysia, while the majority of research is performed in developed countries where the market share is high, such as the United States and Korea (Grimes and Du 2018). There are numerous studies on lean manufacturing that have been conducted using both conceptual and empirical data. However, little focus has been placed on research on lean manufacturing practises carried out in developing countries and how they impact and benefit manufacturing performance (T. Adesta & Prabowo, 2019).

The problems highlighted are summarised to give a better of the influence of lean manufacturing practice, supplier integration, knowledge base engineering, and technological turbulence on operational performance in semiconductor manufacturing, as described below.:

1. Semiconductor manufacturing in Malaysia is facing issue in delivery, cost, flexibility and quality.
2. Lack of understanding of financial and non-financial measurement in operational performance of semiconductor factory.
3. Lack of understanding in factor driving lean manufacturing and supplier integration implementation and contribution toward operational performance in semiconductor factory.
4. Dynamic change of technology affecting factory leverage and use of knowledge asset toward operational performance.

5. Lack of understanding of technological turbulence in semiconductor factory.

The outcome of the research would enable the industry practitioner to understand the problem and potential actions that would enable them to react, adapt, and adopt to enhance factory performance and react better to market technology changes. If the research is not conducted, semiconductor factories in emerging economies will lack references and understanding of their potential contributions to lean manufacturing from a socio-technical perspective, benefit from supplier integration, and make effective use of their knowledge to improve operational performance with a negative moderating effect on technological turbulence risk, despite the fact that semiconductors are one of the industries with the highest levels of uncertainty and complexity in their global value chains (Grimes & Du, 2018).

1.4 Research Gap

The adoption of appropriate performance measures provided crucial performance information and revealed the need for possible changes in operations (Rasi et al., 2015). It is a challenge for firm to make the right choice of performance measure to reduce uncertainty (Orji & Liu, 2020), as incomplete performance measures create incomplete signals for managers (Haseeb et al., 2019). Past research has associated the benefit and contribution toward financial performance rather than intangibles such as firm operational performance in flexibility (Song et al., 2017), where the application of non-financial measurement in operational performance is equally important as financial related measurement (Ahmad & Zabri, 2016). The inclusion of each measurement allows comprehensive information to be communicated to management for appropriate action to be taken according to factory

condition and gives a better reflection of factory capability to achieve its targeted goal (Haseeb et al., 2019).

It is noteworthy that not much research investigates the breakdown of the socio-technical aspects of lean manufacturing toward operational performance, despite the high number of lean manufacturing studies conducted previously (Chavez et al., 2015). Lean manufacturing has been known as an approach in socio-technical terms to help reduce operational costs, improve quality, and decrease both cycle and throughput times, which help with delivery and flexibility (Shah & Ward 2007, Dennis, 2007, Womack & Jones, 1996, Mohammed Iqbal, R., 2011), as well as support the objective of world-class performance in a global marketplace. The use of lean manufacturing has produced positive results in the manufacturing performance of multiple companies (Kumar, 2019), yet the limitation should not only stop at manufacturing but extend beyond the manufacturing environment (Womack et al., 2003). Many prior researches setup to investigate a single dimension of lean manufacturing and its tool as approach to establish association between productivity and quality performance with the goal in respond to customer demand with the aim of waste elimination at the lowest cost (Jia Yuik & Puvanasvaran, 2020), Many of the research explain the association of lean manufacturing toward performance of process and product line (Wyrwicka et al., 2017) oppose to core lean manufacturing implementation that look into the whole value stream of a product line (Liker, 2014). The use of lean manufacturing and research in Malaysia remain low due to likely that lean manufacturing is still at a very early stage among manufacturing firms where it solid contribution and quantifiable result is still questionable (Zailani, et al. 2015).The absent of breakdown of lean manufacturing into socio technical approach (Haseeb et al.,2019) mean that the research framework consists of a set of simplified structures that may not reflect a clear

picture of the benefit and actor that drive effective improvement and explain the inconsistent association of lean manufacturing toward operational performance (Ng & Ghobakhloo, 2018, Costa et al., 2019). The holistic inclusion includes a breakdown into further investigation of the socio-technical approach with human lean practices, which include employee empowerment, middle management support, leadership style, and manager expectation toward operational performance (Maware & Adetunji, 2019), and technical lean practices, which include methodological tools such as continuous improvement and total productive maintenance (Singh & Ahuja, 2012; Henao et al., 2019). These factors are crucial in understanding the factors that drive sustainable lean manufacturing practises as the inclusion of human and technical as a holistic approach (Haseeb et al., 2019) as the inclusion of human and technical as a holistic approach. A successful result depends on the degree of balance achieved between sets of practices of socio- and technical-related nature as the main drivers of operational performance gains in quality, delivery, cost, and flexibility (Belekoukias et al. 2014), which were lacking in previous research.

The discussion on external lean practice discussed how a firm collaborates with interorganizational influence in achieving internal performance metrics (Khalil et al., 2019). The use of supplier integrations targets supplier involvement from the beginning of the development of manufacturing products and thus establishes a partnership relationship to improve operational performance (Kotcharin et al., 2012). Supplier involvement potentially decrease risk, reduce cost , shorten lead time and promote joint development (Naway and Rahmat 2019). Many of the present research papers also define and identify supplier integration as strategic collaboration with suppliers in various approaches, including the degree to which firms are collaborating in idea generation, active inventory sharing, early product development involvement