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Original Article

Assessing Lean Transformation Maturity: A Real-Case Study on Integrating Technical and Cultural Practices for Sustainable Manufacturing in Semiconductor Memory Assembly

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Abstract *- This paper presents the real case study of the implementation and sustainability of Lean Transformation at the high-precision semiconductor manufacturing industry. The SMultinational Company (SMC) in Malaysia is one of the leading providers of high-performance computing and specialty memory products over the past 30 years. After interviews with the quality management team, it was found that the company faced major challenges in improving productivity and achieving cultural change, even after implementing the Lean and Industry 4.0 technologies. Therefore, the study aimed to assess the maturity of Lean practices in terms of technical and cultural aspects, which focus on human factors and sustainable practices aligning with the Industry 5.0 principle in industry. The methodology utilized a structured plantwide survey from the Lean Transformation Maturity Model to get the employee perceptions on the lean effectiveness in the SMC production line. The lean survey focused on three (3) main criteria: Advancing Lean (knowledge and quality tools), Maximizing Lean Impact (Sustainability and Barriers), and Empowering Teams (Lean Cultural Integration). The main findings showed that targeted lean transformation interventions significantly improved the lean understanding and confidence level of employees in this company. However, persistent barriers remained, including resistance to change, limited resources, and a need for greater leadership accountability. The study's contribution is a practical Lean transformation framework that bridges the gaps of Lean practices and the ultimate aim of Industry 5.0. Besides that, the study also presented that a successful transformation hinges on strategic resource allocation, engaged leadership, and a cultural shift that empowers employees, thereby preparing organisations for a more sustainable and human-centric future of manufacturing.*

Keywords *- Lean Culture, Lean Transformation Framework, Maturity Assessment, Semiconductor Industry, Sustainable Manufacturing.*

1. Introduction

Malaysia's semiconductor sector produced RM 50 billion in the year 2024, highlighting the importance of controlling quality in production to remain competitive in the global market and supply chain [1]. The semiconductor manufacturing companies must continuously adapt by leveraging new production methods, technologies, and regulations to maintain the world-class quality products.

A fundamental prerequisite for global competitiveness in the semiconductor industry is systematic elimination of non-value-added processes to enhance operational efficiency and cost-effectiveness. Thus, an essential first step is mapping a simple current-state value stream to determine bottlenecks and inefficiencies of the production line. This method can identify the delay process, and mapping helps pinpoint areas where Industry 4.0 tools can accurately eliminate waste rather than automate the wafer probing process. Implementing robust systems such as the Toyota Production System [2, 3], Lean 4.0 [4–10], frameworks for sustainability, and Industry 5.0 [2, 11–13] is essential for development industries nowadays. The application of such excellent quality tools is also an important factor to improve the reliability of the products, make production efficient, and optimise cost along the semiconductor supply chain.

Lean manufacturing is based on the Toyota Production System (TPS) principles, which are universally applicable concepts that can be applied in various industries and used to minimize waste and enhance efficiency.

Many investigations have proven that lean ideas can effectively improve the performance of manufacturing. In the automotive industry, lean implementation has led to 30-50% reductions in production lead times, and in electronics manufacturing, case studies have demonstrated 25-40% enhancements of productivity [4–6,14]. Meanwhile, from 2011 onwards, the Industry 4.0 concept has been incorporated in the Lean manufacturing system, resulting in people, technologies, and processes being connected into a changing framework of operations and balanced management systems. Frank etc. al [10] reported that companies practicing Lean can reach higher levels of lean implementation by deploying Industry 4.0 technologies in the production line. IoT instruments can capture big data for better decision-making on preventative as well as predictive maintenance. Besides that, Industry 4.0 technologies can change the quality process (PDCE); for example, checking 100% of the products instead of using sampling approaches and automating the quality analysis to avoid additional steps in the production process [2, 11, 15].

The major portion of lead manufacturing is based on its appropriate methodology and tools. It also depends upon the leadership, participation of management, attitude of the employees, and culture of the organisation, which is in line with the concept of Industry 5.0 (sustainable, human-centred and resilient production) [12]. With the introduction of new lean production approaches, technologies, or regulatory requirements, manufacturing companies are facing transformation processes. To sustain the transformation effect, it is important to identify the barriers and assess lean development practices in the manufacturing company [7, 9, 10]. From the current literature search, it has been revealed that many industries have successfully implemented the lean initiative to achieve early productivity gains. However, the organisations faced the difficulty of sustaining productivity and embedding Lean culture among employees. Besides that, inconsistent employee involvement, inadequate Lean knowledge dissemination, and leadership commitment are huge challenges to obtaining the Lean benefits. Many organizations stated that during the lean introduction, the key barrier is the workforce's understanding and commitment to lean, and as they move forward in the lean journey, top management commitment becomes more critical to their success. Lean transformation implementation can be considered as any other major change initiative. As a change, this is not an ad-hoc project or solution, but rather a continuous process with impact both on processes and people. Meanwhile, Priyo Setianto and Abubaker Haddud [14] conducted research related to the evaluation of lean maturity levels for manufacturing industries in Qatar. They established that most of the manufacturing organisations surveyed were ‘average’ and ‘above average’ in their level of lean practice, with few problems mainly concerning the KPI targets setting, absence of support from leadership, management commitment, and lack of communication medium. For organisations to be successful, a lean culture has to be established that promotes leadership commitment, workforce involvement, and social support systems. While previous research has well-documented the lean benefits, barriers, challenges, and even maturity levels of Lean implementation, a significant gap remains in the Lean development study, which lacks a structured framework for cultivating a sustainable Lean culture. This phenomenon is also observed in this case study at S Multinational Company (SMC). Despite adopting lean principles and Industry 4.0, the company has not been able to improve its high rates of rejection or increase productivity as expected. In short, the research question is: "What are the main factors preventing the integrated Lean and Industry 4.0 initiative from improving productivity and lean culture at SMC production line?" Thus, this study examines how Lean Transformation culture and techniques can be effectively implemented and sustained in the real case study on the memory storage assembly process in the SMC company. This study is to assess both cultural and technical aspects of Lean adoption through the structural framework, understand prevailing challenges, and identify areas requiring strategic focus.

2. Research Methodology

2.1. Company Background

S Multinational Company (SMC) is a global designer and supplier of memory solutions founded in 1988. The company has built a significant technology base in high-performance computing and specialty memory products over the past 30 years. Its portfolio is deployed in Industry 4.0 applications, including AI, ML data centers, and automation systems. SMC's products include data encryption, high-speed communication, and memory sharing, which are indispensable for secure and efficient data processing in HPC environments. It incorporates customer requirements into design and production processes and adheres to strict quality control systems and supply chain management standards to deliver the best products with optimal performance, reliability, and consistency.

Despite adopting lean principles and Industry 4.0, the company has not been able to improve its high rates of rejection or increase productivity as expected. Against this background, in the plantwide online survey, the maturity of Lean Transformation initiatives at the organizational level was explored in the current study. This provides an in-depth review of the survey data that represents the development of lean maturity within the organisation. Using a combination of quantitative and qualitative answers, it assesses employee behaviours, which includes Lean practices, confusing the lean principles, and how the organisation addresses its challenges. The findings are an important contribution to the development of future interventions towards creating Lean thinking in the manufacturing industry. The assessment survey provides benchmarks or reference data, comparing the before and after Lean transformation framework to measure the impact on productivity.

2.2. Lean Maturity Assessment (LMA)

The Lean Transformation Maturity Assessment model is designed to evaluate the extent, effectiveness, and sustainability of Lean implementation in organizations [15, 16]. This assessment method is divided into three main sections reflecting SMC's Lean performance: Advancing Lean, Maximizing Lean Impact, and Empowering Teams via Lean. Each section targets specific evaluation criteria through focused assessment questions. These elements were designed to capture not only the technical adoption of Lean tools but also the behavioral, cultural, and strategic alignment necessary for a sustainable Lean transformation. The review is structured into three groups, as shown in Table 1, which underpins hypothesis development for Lean transformation in manufacturing.

Table 1. Maturity assessment criteria

Maturity Assessment: Lean Transformation in SMC		
Category	**Criteria**	**Assessment Questions**
A	Advancing Lean: Transformation, Tools, and Principles	A1: Understanding of Lean Transformation A2: Improved Knowledge of Lean Tools A3: Application of Lean Principles
B	Maximizing the Impact of Lean: Transformation, Tools, and Sustainability	B1:Value of Program Activities B2: Barriers to Sustaining Lean Practices B3:Support for Lean Practices
C	Empowering Teams through Lean: Effectiveness, Impact, & Cultural Integration	C1: Effectiveness of the Program C2: Impact on Team Practices

2.2.1. Category A: Advancing Lean – Transformation, Tools and Principles

A1: Understanding of Lean principles

The level of understanding of employees on lean philosophy, not merely the implementation of tools, but rather also includes changes in lean thinking, culture of continuous improvement, or strategic direction. Assessment criteria used are derived from questions concerning employee awareness of Lean goals, its organisational significance, and transformation as a systemic process.

A2: Improved Knowledge of Lean Quality Tools

Understanding and being capable of implementing Lean tools such as 5S, Value Stream Mapping, Kaizen, Kanban, and Visual Management are essential for operational excellence, the employee's familiarity with these tools, and confidence in their use after training or workshops.

A3: Application of Lean Principles

Beyond knowing Lean, it is critical to evaluate how frequently and consistently these principles, such as waste reduction, pull system, and effective communication within the team, are applied in operation. Questions in this criterion explore the practical translation of Lean thinking into the workplace in the production line.

2.2.2. Category B: Maximizing the Impact of Lean – Transformation, Tools and Sustainability

B1: Value of Program Activities

This criterion captures the employee feedback on which Lean activities (such as workshops, idea generation sessions) have been most useful. Emphasises sustainability and resiliency of Lean practices over the long term, as well as perceived value across different types of program interventions.

B2: Barriers to Sustaining Lean Practices in an Organisation

Investigates obstacles during the implementation of lean practices and emphasises the importance of support for continuing the lean efforts. Sustaining Lean practices is one of the company's major challenges.

To address the obstacles, such as a lack of management support, a lack of resources for training, poor initial training, and employee involvement, that can reduce the effectiveness of lean practices.

B3: Support for Lean Practices

The long–term success of Lean depends significantly on internal champions. This sub-category evaluates employees' willingness to advocate for Lean, promote its benefits to others, and serve as role models in Lean behaviour, which reflects both cultural acceptance and implementation of Lean values.

2.2.3. Category C: Empowering Teams through Lean – Effectiveness, Impact, & Cultural Integration

C1: Effectiveness of the Program

This scale is based on program success perceived with respect to Lean knowledge, skill, and attitude. Efficiency is assessed and monitored through the employees' feedback with respect to learning effects and the practical suitability of the Lean training program.

C2: Impact on the Team about the Lean Practices

A lean transformation should make not only single work station tasks better, but also enhance collaboration, communication, and problem-solving within production teams. This sub-section focuses on how Lean has influenced the behaviours and processes of the employee.

C3: Cultural Acceptance of Lean

Lean is truly mature when it becomes part of the culture. This is an assessment of Lean activities with respect to strategic alignment and intensity of commitment throughout all levels of the management teams in the company. Therefore, these categories provide the evaluation of promoting lean sustainable organisational transformation and performance improvement in terms of lean culture.

2.3. Data Collection_ Survey Design

A survey approach to the evaluation method was adopted to evaluate the maturity of Lean Transformation at SMC Company. The assessment was based on the Lean Transformation Maturity Model (LTMM), which is a diagnostic tool developed to determine the level of maturity of the organization's transition to lean practices. Instrument: The survey instrument was designed by reviewing the lean maturity model from Table 1, then tailored for the SMC company's operative context in terms of:

- Production and Assembling Processes Workflows (SMT lines, autoloader process, etc.)
- Structure of the Organisation and Participation of Leadership.
- Lean implementation efforts are underway at present.

To objectively measure responses, each question was linked to a five–level Lean maturity scale derived from the literature on Lean transformation (as shown in Table 2 above). Nearly 80% (804/1016) of the management team and production workers participated in the survey response to every maturity level and computed an overall Lean maturity score by aggregating these at the category as well as at the company level.

Table 2. level of lean maturity assessment scale

Level	Categorization	Definition
1	Initial / Ad hoc	Lean efforts are informal or absent; no structured practices.
2	Developing/ Emerging	Some Lean tools are in place; inconsistent implementation and understanding.
3	Defined / Standardized	Lean practices are formalized and partially embedded across departments.
4	Managed / Measurable	Lean practices are systematically deployed, and performance is tracked.
5	Optimized / Sustained	Continuous improvement is implemented; Lean culture is self-reinforcing.

In order to be effective, the choice of Lean tools was tailored to the company's maturity level as identified within the survey-based assessment. These maturity levels determined the deployment and reproducing tooling of Lean into the organisation in a way that fit its readiness and led to better Lean deployments.

The tool selection was informed by a dual–framework integration of Lean Manufacturing and Lean Six Sigma, which together form the foundation for companies' ongoing Lean Transformation initiatives. Based on maturity, implemented a phased tool-deployment roadmap & strategy as a reference for Table 3.

Table 3. Lean tool focus and development on maturity level

Maturity Level	Tool Focus	Purpose
Level 1–2	5S, Waste Identification, Basic Visual Boards	Awareness, Workplace Discipline, Team Engagement
Level 3	Kaizen, Standard Work, Kanban,	Process Stabilization, Ownership, Team-based Activity
Level 4	VSM, DMAIC, Andon, Cross–functional Kaizen	System Optimization, Root Cause Elimination
Level 5	PQDCSM Metrics, Integrated Lean Six Sigma, Cultural Deployment	Sustained Operational Excellence

For organizations and teams at Levels 1 through 3 (Initial to Defined), tools were chosen to enhance awareness, normalize operations, and develop basic abilities. These included:

- 5 S (Sort, Set in order, Shine, Standardize, and sustain): it is practiced throughout the organization as a milestone to create orderliness and maintain discipline at the place. 5S audits became part of daily work routines, facilitating early visual management and flow improvements.
- Visual Management (Andon, Kanban): This was to improve shop floor visibility and ultimately reduce downtime, assist decision making at the point of work. Visual boards and Kanban cards enjoyed widespread application in SMT lines for controlling component flow and minimizing material loss.
- Waste Diagnosis (8 Wastes): Used for diagnosing the frontline team to identify non–value adding activities. Classroom training focused on recognizing overproduction, transport waste, and wasted motion in SMT assembly.
- Kaizen Events: These are the events that started at one sub-process level to solve a specific problem in that area. These short-term-oriented events helped raise confidence and escalate the culture of improvement.

For areas exhibiting Level 4 or higher maturity (Managed to Optimize), more integrated and analytical tools were adopted to drive continuous improvement and system–wide optimization:

- Value Stream Mapping (VSM): Used to analyze end – to – end material and information flow. At the company, this was especially useful in identifying bottlenecks in SMT machine feeder loading and batch release cycles.
- Define, Measure, Analyze, Improve, Control (DMAIC): As part of Lean Six Sigma integration, DMAIC projects were launched for issues requiring structured root cause analysis, such as yield variation and equipment downtime.
- Performance Management (PQDCSM): Lean metrics were aligned to Lean principles and tracked through the productivity, defect numbers, delivery date, cost per batch, and safety issues. These KPIs enabled ongoing measurement of Lean impact and were supported with customer and employee feedback in continuous improvement cycles.

Lastly, to capture a representative organisational perspective, the survey was disseminated across multiple functional and hierarchical levels within the organisation. Respondents comprised Process Owners and Engineers (35%), Production Supervisors and Line Leaders (30%), and personnel from Support Functions such as Quality, Maintenance, and Logistics (25%), together with Senior and Middle Management (10%). A total of 89 valid responses were obtained over three weeks.

The survey was administered digitally through an internal platform, and participant confidentiality was maintained to minimise response bias and promote candid feedback. The assessment survey provides an extended dataset, comparing before and after Lean metrics to quantify productivity impacts.

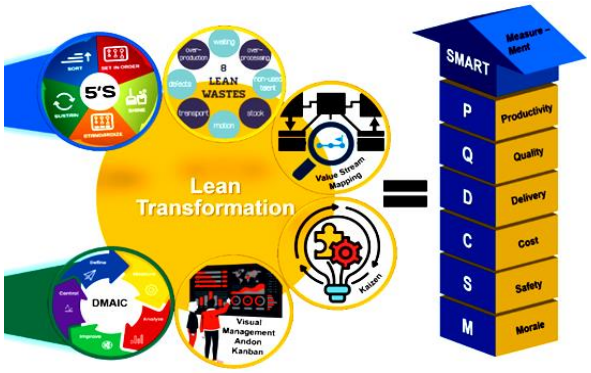

Fig. 1 Lean transformation tools & Measurement criteria

The structured selection and deployment of Lean tools, as illustrated in Figure 1, were directly explained by the assessed maturity levels. This ensured that tools were neither underutilized in high-maturity areas nor overdeployed in low-readiness departments, minimizing resistance and maximizing impact. The integrated use of Lean Manufacturing and Lean Six Sigma frameworks provided a flexible, scalable approach to Lean Transformation across production systems.

2.4. Plantwide Lean Transformation

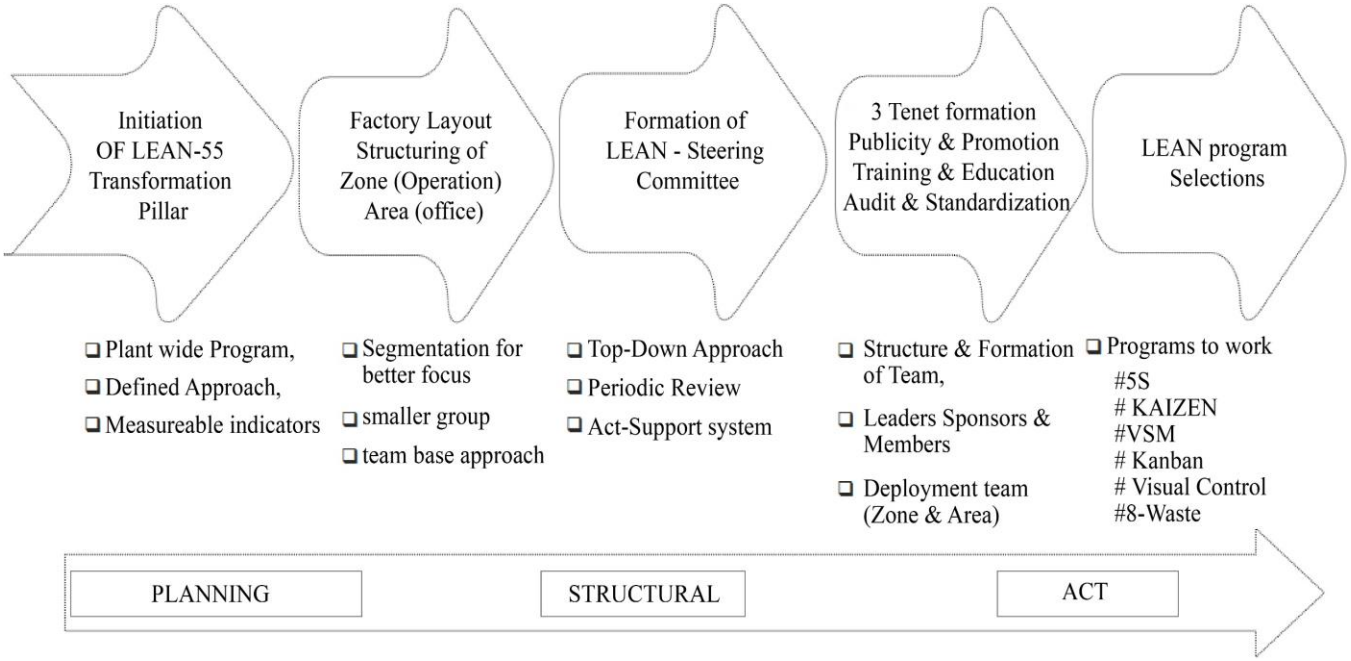

Fig. 2 Phases of examine and implement lean transformation in memory storage assembly

Consequently, to address the lack of empirical evidence, this study analyzes a real-case study of a manufacturing plant that implemented a phased Lean Transformation strategy to advance its lean maturity with mediator systematically and moderator factors in the manufacturing company [5, 10, 17, 18]. This structured program, consisting of Planning, Structural, and Act stages, guaranteed consistent implementation, aligned leadership, and durable results. Every stage incorporated clear activities, designated responsibilities, and quantifiable metrics to track progress as illustrated in Figure 2.

The Planning Phase Initiation of Lean Transformation Pillar, the first step, involves establishing Lean as a core pillar of productivity improvement. The Lean initiative can be defined as a comprehensive plantwide program to avoid isolated improvements with the Lean transformation framework, where a roadmap with milestones, KPIs, and a timeline was prepared. The cycle time, defect rate, and downtime are the measurement indicators for this framework to track progress and build credibility. This is to ensure the Lean practices were not treated as a short-term project but as a strategic transformation initiative integrated into daily operations.

The structural phase focused on structuring the plant for Lean transformation through segmentation, leadership alignment, and governance.

- The company is structured into different Zones/Areas, which are operational and areas of office for better focus and accountability. Smaller functional zones were formed to create ownership among employees in this company. A team-based approach encouraged problem-solving at the ground level.
- Formation of the Plant Leadership Committee in this lean transformation program, where a Lean Steering Management Committee was established to drive governance in the zone. Leadership adopted a top–down approach, ensuring alignment between SMC company goals and shop-floor execution, with periodic monitoring conducted to assess progress, address challenges, and allocate resources.
- Building a Lean Culture and Skills, Lean transformation was publicised internally through communication campaigns, awareness programs, and visual promotion. Training and Education sessions were conducted to upskill employees, and audits were introduced to sustain the lean practices. A deployment team consisting of sponsors, leaders, and members was created for each zone and area.

This framework enabled a systematic, inclusive, and scalable deployment of Lean in the production line. This disciplined phased approach ensured that Lean implementation would be systematic, measurable, and tailored to the production's maturity. By cascading from planning to execution with clear governance and programmatic selection, the approach guaranteed that each Lean initiative provided tangible improvements before moving to the next, leading to a sustainable plantwide Lean culture in the SMC company.

3. Result and Discussion

As a starting point, the study has evaluated current lean effectiveness by analyzing the eight classic wastes, providing a diagnostic baseline for targeted improvement within a semiconductor fabrication plant, as shown in Figure 3.

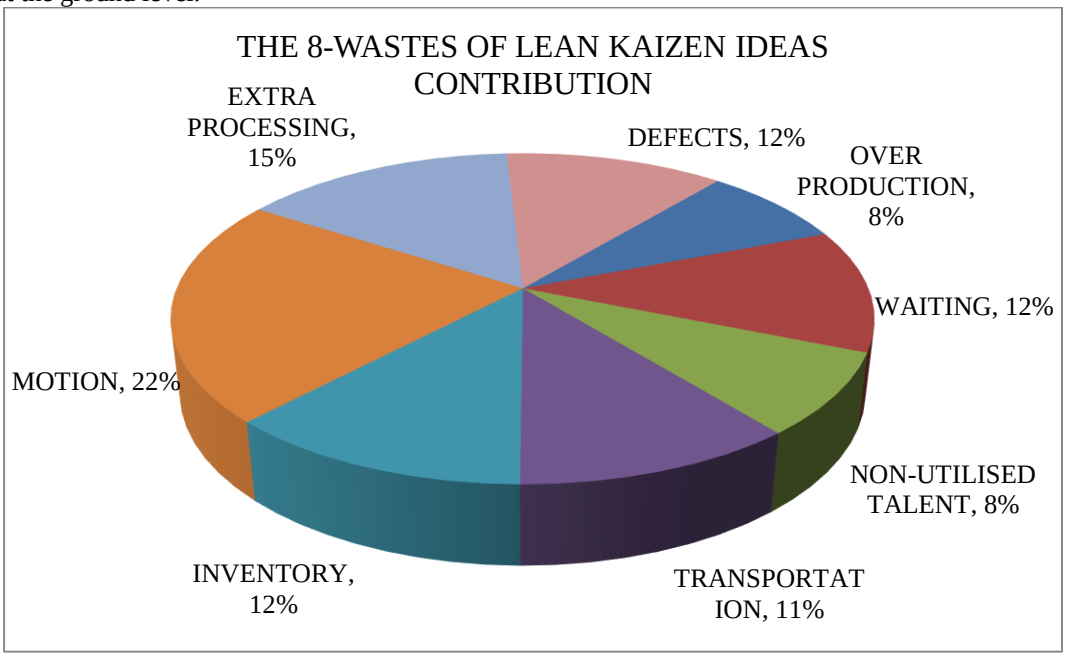

Fig. 3 Eight wastes in the memory storage assembly process

The resulting data reveals valuable information on recurring operation problems. Motion,40 occurrences, and Extra Processing, 27 occurrences, are the significant forms of muda. These significantly outweigh Over Production and Non-Utilised Talent, each with 15 occurrences. The prevalence of Motion waste indicates a substantial lack of organization in the workplace. This is consistent with prior research [18], which found deficient 5S application as the leading cause of operational delays in high-tech manufacturing. Technicians waste much time on non-value-added tasks, whether it is looking for that tool or getting the line information. This has induced the reduction of Overall Equipment Effectiveness (OEE) for the production process [2]. Furthermore, the fact that Extra Processing is likely due to the over-designing and excessive quality checks. As Kumar et al. [19] have claimed, the main components of lean thinking are to reduce the complex design and manage the customer needs based on the product requirements.

The process redundancies represent a waste in terms of work, manpower, materials, and assets in lean practices. It can be seen that the over-processing described herein is directly related to the waste from ‘produce defects’ and ‘waiting’, both with 23 appearances, pointing out two other significant obstacles. The product defects are catastrophic in the semiconductor production line due to the high value of Work in Progress (WIP) and bottleneck issues. Simultaneously, the waiting waste is the idle time of both equipment and WIP, which reflects imbalances in production planning and scheduling. In the same way, the findings also have good agreement with Wang et al.'s [20] study. They have found that even minor waiting times at bottleneck tools exponentially increase cycle times in semiconductor manufacturing. In short, this waste analysis provides a clear investigation for this company in terms of lean effectiveness and highlights that a long-term focus on building the Kaizen project is essential to achieve sustainable improvement.

As mentioned in the earlier statement, although the lean practices and Industry 4.0 principles have been implemented in such a company, it still experiences very large amounts of waste that limit the attainment of perfect operational performance. Thus, the lean maturity assessment of the plant’s Lean performance has been considered in the next study to provide the quantitative evidence for Areas of improvement in the production line.

3.1. The Evaluation of Criteria A

For a Lean transformation to be successfully implemented and deliver effective results in reducing the lean wastes in the company, all employees must have a solid understanding of the Lean principles [15]. The evaluation of Lean awareness and confidence level of employees before and after the Lean transformation training interventions (Figure 2) is illustrated in Tables 4, 5, and 6. Initially, there were widespread misconceptions about Lean principles: 90% of the employees believed that Lean practices primarily involved high investment costs, and 30% of the employees associated it with reducing headcount in the IR 4.0 elements. Such perceptions changed vastly after the transformation training, and the most significant finding was that the "Improving Organizational Efficiency" increased dramatically from 23% to 88.8%.

This is likely due to the transformation framework, Figure 2, the Initiation and Planning phases directly addressed the lean misconceptions through the initiative of "3 Tenets-Publicity & Promotion, Training & Education, and Audit & Standardization". These findings represent that lean knowledge is expanding in terms of greater recognition as a cultural and technological change in the company, which is consistent with claims that digitalisation fosters the practice of Lean [17].

This phenomenon also contributed to the greatest obstacles, as shown in Table 5, the lack of knowledge (70%) and Misalignment of goals and strategies (90%). After the transformation training, although the two obstacles were reduced, new difficulties appeared, including ‘ Resistance to change’, which increased from 40% to 51.7%. This indicated that the company has correctly determined that the primary barrier is not the lean technical issues but the cultural factor in the production line. To overcome this, it requires the persistent engagement of top management and workers to embed a mindset of Kaizen into daily operations.

The top management involvement has been well documented in previous studies [10, 18, 19], and it can effectively overcome cultural resistance during organisational change efforts. By establishing a two-way communication system that values every employee's input and empowers them to improve their work, the organisation can unlock the most powerful resource in the production line: employees' intellect and creativity. This cultural element will create a Lean transformation that is sustainable in the long term.

Lastly, before the transformation training, 98% of employee respondents reported ‘not confident’ in applying the lean activities in their work station. Following the training, confidence increased markedly, with 43.8% indicating moderate confidence and 42.7% reporting high confidence (Table 6). These outcomes support prior research highlighting the importance of capacity building and experiential learning in Lean implementation [7-9]. When employees are given the opportunity for Kaizen, appropriate resources, and encouragement to enhance their immediate work environment, they will become actively engaged in problem-solving of waste as listed in Figure 3. This empowered employee is the driving force to achieve continuous improvement, as employees possess both the capability and the motivation to enhance the quality in their daily tasks.

Table 4. Pre- and post–Lean metrics for Criteria A (1.1): Lean Transformation" primarily focus on?

Criteria A: 1.1) What does "Lean Transformation" primarily focus on?		
Element	**Before**	**After**
Reducing headcount	30%	6.7%
Improving organizational efficiency	23%	88.8%
Increasing costs	90%	2.2%
Automating all processes	3%	25.8%

Table 5. Pre- and post–Lean metrics for Criteria A (1.2): Challenges in implementing Lean Transformation

Criteria A: 1.2) What challenges do you think organizations face in implementing Lean Transformation?		
Element	**Before**	**After**
Resistance to change	40%	51.7%
Lack of resources and expertise	70%	41.6%
Difficulty sustaining improvements	20%	47.2%
Misalignment of goals and strategies within organizations	90%	31.5%

Table 6. Pre- and post–Lean metrics for Criteria A (2): Confident level of labour.

Criteria A: (2) How confident are you in applying Lean principles in your daily work?	Before	After
Not confident	98%	0%
Slightly confident	54%	10.1%
Moderately confident	30%	43.8%
Very confident	15%	42.7%

The lean cultural shifts are directly reflected in the implementation of lean quality tools for productivity improvement. From Table 7, employees' comprehension of lean quality tools increased significantly. Employees' understanding of Lean tools showed clear improvement, with the 5S quality tool increasing from 20% to 63%, the Kaizen concept from 10% to 70%, and the 8 Wastes definition rising by 14% to reach 71%. These enhancements demonstrate the success of lean transformation training at the Act phase 'Lean Program Selection', Figure 2, to clarify the basic Lean principles in the semiconductor production line. However, the tools Value Stream Mapping (3%) and DMAIC (0%) still evidenced knowledge gaps, and the employees need more in-depth or successful case studies to sustain forms of training. Overall, the outcomes from the survey assessment indicate that structured Lean transformation training can significantly lead to enhancement in knowledge of the lean concept, confidence level of employees, and lean culture in the production line, but barriers such as resistance to change of employees and advanced lean quality tools use must still be addressed to sustain the lean practices.

Table 7. Pre- and post–Lean metrics for Criteria A (3.0): Improve knowledge of Lean tools

Criteria A: 3.0 Improve knowledge of Lean tools:	Unfamiliar	Aware	Knowledgeable	Competent
	Before			
5S	40%	78%	20%	5%
VSM	70%	80%	18%	3%
KAIZEN	50%	34%	10%	1%
DMAIC	95%	67%	5%	0%
After				
5S	0%	9%	63%	27%
VSM	5%	23%	64%	5%
KAIZEN	2%	16%	70%	13%
DMAIC	3%	34%	54%	9%

3.2. The Evaluation of Criteria B

Transformation in lean implementation regarding the lean program activities, leadership Support on the lean practices, and Strategic Alignment with the lean improvement are further assessed as illustrated in Table 8. The survey results emphasise the growing maturity of Lean knowledge and support among employees, as well as the role of leadership in sustaining Lean practices in such a company.

Among various lean program activities, as shown in Table 8 (a), Criteria B (1.1), Kaizen idea generation was found to be the most profitable to the productivity with an increasing percentage change from 30.8% to 53.9%. In comparison, early stages of lean activities (MUDA) focused on Lean Tournaments (32.6%) and Waste Identification (34.8%), showing a progressively decreasing value after the training program. The positive shift of Kaizen idea generation indicated that employees have embedded a culture of continuous improvement mindset, consistent with Lean principles that emphasize frontline engagement and bottom–up innovation as key drivers of success.

Moreover, through structured workshops and mapping exercises in the lean transformation program, employees in the company now demonstrate a clear preference for action and empowerment over theoretical analysis. The program has successfully transitioned the culture in the company from creating awareness to the continuous improvement mindset, which is an approach that aligns closely with the human-centric and sustainability goals of modern Industry 5.0 [12].

Table 8. Results of Criteria B – Maximizing the Impact of Lean – Transformation, Tools, and Sustainability

a) Criteria B:(1.1)Which program activity did you find most beneficial?	Before	After
Lean workshops	55.4%	46.1%
KAIZEN idea generations	30.8%	53.9%
Waste Identifications	67.9%	34.8%
Value stream mapping exercises	40.3%	25.8%
Lean Tournament	66.9%	32.6%

b) Criteria B:(2.1)What is the biggest challenge in sustaining Lean practices?	Before	After
Lack of management support	56%	22.5%
Limited resources	30%	49.4%
Inadequate training	70%	24.7%
Lack of participant/engagement	98%	67.4%

c) Criteria B : (2.2) What role does leadership play in sustaining Lean practices in your organization?	Before	After
Providing consistent support and guidance	70%	58.4%
Ensuring accountability and follow-through	65%	33.7%
Encouraging a continuous improvement culture	30%	67.4%
Offering regular training and resources	20%	37.1%

d)Criteria B : (3.1) How likely are you to promote Lean principles in your workplace?	Before	After
Very unlikely	15%	2%
Unlikely	23%	0%
Neutral	60%	26%
Likely	55%	48%
Very likely	3%	25%

e)Criteria B : (3.2) What motivates you to continue advocating for Lean practices?	Before	After
Belief in its effectiveness	12%	52%
Positive outcomes from previous initiatives	87%	51%
Encouragement from colleagues of the leadership	79%	37%
Personal interest in continuous improvement	32%	45%

Even with incremental advances, maintaining Lean is difficult. A previous study demonstrated that leadership and resource allocation are the main barriers to sustaining lean activities in a production line [20]. Thus, the main objective of the lean transformation training is to enhance the top management's involvement through the deployment of Lean. Thus, a significant drop in Lack of management support (56% to 22.5%) and Inadequate training (70% to 24.7%). This is a direct outcome of the framework's "Top-Down Approach" and "Training & Education" initiative from the training framework. Besides that, the formation of a "LEAN – Steering Committee" and "Leaders Sponsors" made management support visible and structured in such a lean transformation program. The role of leadership in sustaining Lean was further explored. Most of the employees in the company (67.4%) were aware of the role of leadership to promote a culture of process improvement, and 58.4% agreed on regular support and direction availability. However, only 33.7% identified accountability and follow-through as strong aspects, suggesting a gap in performance oversight mechanisms. As emphasized in previous studies, successful lean leadership requires not just motivational support but also the time, budget, and authority for teams to sustain improvements over time.

The encouragement from the top management in the company, and employee support for Lean transformation have improved. Before the intervention, only 13% reported they were likely to promote Lean in their workplace. After they fully understood the lean transformation program, the willingness to promote the lean initiative increased to 48%.

Factors in driving employees' motivation shifted from extrinsic ("Positive outcomes," 87% to 51%) to intrinsic ("Belief in its effectiveness," 12% to 52%). This is the ultimate aim of the entire framework.

The combination of Training, team-based lean activity, and leadership focus on culture has led employees to internalise Lean as a self-improvement in the production line, not just a corporate program.

3.3. The Evaluation of Criteria C

This criterion is used to evaluate the effectiveness of the Lean transformation program, as listed in Table 9. These results show the positive impact of targeted lean training in the production line and well-aligned interventions from the management team. The effectiveness of lean activities increased significantly, moving from 'Not Effective' (1%) level to 'Very Effective' (51%) level. This improvement demonstrates that the lean initiative can mitigate the major challenge: the lack of "know-how" in manufacturing companies. The 'ACT' phase in the current transformation framework, with its "Periodic Review" monitoring phase, transforms one-off training into a continuous improvement cycle (Kaizen). This structured reflection allows the employees to move beyond theoretical knowledge and develop a deep understanding and apply Lean principles effectively in their workstation.

Table 9. Results of Criteria C – Empowering Teams through Lean –Effectiveness, Impact, & Cultural Integration

Criteria C: 1.1) How effective was the program in enhancing your knowledge of Lean principles?	**Before**	**After**
Not effective	43%	1%
Slightly effective	35%	8%
Moderately effective	23%	38%
Very effective	19%	51%
Extremely effective	3%	6%

Criteria C: 2.1) Have you noticed changes in your team's approach to addressing inefficiencies?	**Before**	**After**
No changes	53%	4%
Minor changes	65%	21%
Moderate changes	28%	62%
Significant changes	14%	15%

Criteria C: 3.1) Do you believe Lean practices are now embedded in your team's culture?	**Before**	**After**
Strongly disagree	21%	2%
Disagree	20%	6%
Neutral	85%	35%
Agree	17%	55%
Strongly agree	11%	14%

The 'ACT' phase in the transformation program is designed to make the benefits of Lean visible and tangible at the production line. The "Periodic Review" forces regular monitoring and determines inefficient processes through the tangible measurable results (productivity and defect units). This process provides concrete evidence that Lean practices in the production line are securing buy-in and demonstrating their long-term value. The data confirms that employees are not just learning from the lean workshop but are actively and observably changing their workflows, minimising the non-value added process, proving the sustainable impact of Lean on their workplace operations. The surge in "Moderate changes" in team approaches (from 28% to 62%) directly addresses the challenge identified by Henao et al. [10] regarding the failure to properly identify, prove, and address the implications on long-term sustainability, which is in good agreement with the finding in Criteria C: 3.1, Table 9.

Thus, it can be concluded that the multi-criteria maturity assessment clearly shows that Lean knowledge, implementation, and culture have transformed in the memory storage production line. The assessment fell into three broad categories: Advancing Lean understanding, Maximising the Impact of Lean activities, and Empowering employees via Lean transformation program, and each reflected interesting insights.

4. Conclusion

Based on the lean transformation case study at SMC in Malaysia, the following conclusions are drawn:

The structured Lean transformation program significantly improved employees' Lean technical knowledge and cultural alignment within the company. SMC Employees improve their understanding of Lean principles from cost-cutting to efficiency enhancement in the production line, with 88.8% recognising it as a tool for rising productivity. The confidence level of employees in implementing Lean initiatives has increased dramatically from 2% to 86.5%. The transformation progressed from a basic waste identification step to an aggressive focus on continuous improvement in the production line. The Kaizen idea generation became the most value-added initiative among the production employees (53%), which indicates that the company's cultural shift from problem to proactive problem-solving. It is believed that this transformation program will enhance the working quality of the production team and cultural integration. In fact, 62% of employees reported ‘moderate changes’ in addressing inefficiency processes, and 69% of employees agree that Lean practices are embedded in their working culture to increase productivity in the company. Besides that, the lean transformation program's effectiveness increased substantially, with those employees rating the lean practice for "very effective" rising from 19% to 51% after the training program. In short, the sustainable lean transformation framework for SMC has addressed barriers by improving resource allocation, strengthening leadership commitment, and empowering frontline employees. The findings from this study have confirmed that the Lean transformation program in mass production requires optimising the effectiveness of lean technical tools with human-centric approaches, aligning with Industry 5.0 aims for future manufacturing excellence.

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