A CONTINGENCY-BASED DECISION SUPPORT INSTRUMENT FOR SELECTING LEAN PRODUCTION TOOLS AND TECHNIQUES

MOHD SHAHIR BIN YAHYA

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

STATUS CONFIRMATION FOR DOCTORAL THESIS

A CONTINGENCY-BASED DECISION SUPPORT INSTRUMENT FOR SELECTING LEAN PRODUCTION TOOLS AND TECHNIQUES

ACADEMIC SESSION: 2020/2021

I, **MOHD SHAHIR BIN YAHYA**, agree to allow this Thesis to be kept at the Library under the following terms:

1. This Thesis is the property of the Universiti Tun Hussein Onn Malaysia.
2. The library has the right to make copies for educational purposes only.
3. The library is allowed to make copies of this Thesis for educational exchange between higher educational institutions.
4. The library is allowed to make available full text access of the digital copy via the internet by Universiti Tun Hussein Onn Malaysia in downloadable format provided that the Thesis is not subject to an embargo. Should an embargo be in place, the digital copy will only be made available as set out above once the embargo has expired.
5. ** Please Mark (√)

☐ CONFIDENTIAL (Contains information of high security or of great importance to Malaysia as STIPULATED under the OFFICIAL SECRET ACT 1972) *Title and Abstract only*

☐ RESTRICTED (Contains restricted information as determined by the Organization/institution where research was conducted) *Title, Abstract and Introduction only*

☐ EMBARGO __________ until __________
(date) (date)

[√] FREE ACCESS

Approved by,

(WRITER'S SIGNATURE) (SUPERVISOR'S SIGNATURE)

Permanent Address:

NO 215 KG. PARIT DAUN DARAT
86400 PARIT RAJA,
BATU PAHAT, JOHOR

Date : 27 May 2021 Date: 27 May 2021

NOTE: ** If this Thesis classified as CONFIDENTIAL or RESTRICTED, please attach the letter from the relevant authority/organization stating reasons and duration for such classifications.

This thesis has been examined on date ......18 March 2021...... and is sufficient in fulfilling the scope and quality for the purpose of awarding the Degree of Doctor of Philosophy

Chairperson:

PROF. IR. DR. SAIDIN BIN ABD WAHAB
Faculty of Mechanical and Manufacturing Engineering
Universiti Tun Hussein Onn Malaysia

Examiners:

PROF. DR. DZURAIDAH BINTI ABD WAHAB
Faculty of Engineering and Built Environment
Universiti Kebangsaan Malaysia

PROF. DR. YUSRI BIN YUSOF
Faculty of Mechanical and Manufacturing Engineering
Universiti Tun Hussein Onn Malaysia

A CONTINGENCY-BASED DECISION SUPPORT INSTRUMENT FOR SELECTING LEAN PRODUCTION TOOLS AND TECHNIQUES

MOHD SHAHIR BIN YAHYA

A thesis submitted in
fulfilment of the requirement for the award of the Degree of
Doctor of Philosophy.

Faculty of Mechanical and Manufacturing Engineering
Universiti Tun Hussein Onn Malaysia

JUNE 2021

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged

Student : ……………………………...…….
MOHD SHAHIR BIN YAHYA

Date : 27 May 2021
………………………………………

Supervisor : ………………………………………
ASSOC. PROF. Ts. DR. MUSLI BIN MOHAMMAD

Co Supervisor : ………………………………………
PROF. DR. BADRUL BIN OMAR

ACKNOWLEDGEMENT

First and foremost, I would like to express my greatest appreciation to my supervisor, Associate Professor Ts. Dr. Musli bin Mohammad and also my co-supervisor Professor Dr. Badrul bin Omar for the profound guidelines, professional supports and sincere of advice throughout the research.

I also would like to thank all my colleagues, who always advised me about my work, and provided me with a pleasant and comfortable working atmosphere.

For financial support, I would like to acknowledge Research Management Centre, Universiti Tun Hussein Onn Malaysia who had approved grants for this project. This research project was financially supported by TIER 1 under grant number H171.

Finally, my deepest appreciation goes to all my family members for their permanent support during my research journey.

ABSTRACT

This study is about the development of decision support instrument for selecting lean tools and techniques based on the contingency factors to help Malaysian organizations to select the right lean tools and techniques based on their context. Most of the prior studies were found focusing on the selection lean tools but did not assess the critical contingency factors that may influence the selection of lean tools and techniques. Adding to that, there were no similar studies on the selection of lean tools and techniques within the Malaysian context. The right tools and techniques to be used may vary depending on several factors, therefore to keep away from unnecessary waste and dissatisfaction, it would be better for organization to choose the right lean tools and techniques that will fit with organization's situation and give benefits to the organization. A mixed-methods study exclusively focused on the development, evaluation, and refinement of a decision support instrument or specifically known as "**De**cision **A**id for **L**ean Tools and Techniques **S**election" (DEALS) was used. The developed decision support instrument, which incorporates 10 most widely used lean tools and techniques was emphasises the use of holistic processes which start from diagnose their current state of waste until the guidance of selecting the appropriate lean tools and techniques. Additionally, contingency factors were employed to include multifaceted viewpoints and contexts in the development of DEALS, such as the adeptness to acquire the commitment and support from the top management and the advantages of implementing lean tools and techniques. The developed decision support instrument includes two selection methods, namely (1) simple additive weighting (SAW) for basic selection and (2) analytic hierarchy process (AHP) for more advanced selection. Based on the evaluation results, all respondents (100%) agreed on the usability, accuracy, and novelty of DEALS as well as the relevance and validity of the selection and the clarity of the purpose of DEALS. The final results of

validation testing also shows less than 5% errors when comparing final results of DEALS with two established software which are Expert Choice 11 software and Super Decision Software. By having this DEALS, it expected significantly benefit to managers, practitioners, consultants, researchers, and academicians as a guidance instrument in the selection of lean tools and techniques and generally to organization to have knowledge workers.

ABSTRAK

Kajian ini adalah mengenai pembangunan instrumen sokongan bagi membantu membuat keputusan dalam memilih alat dan teknik lean berdasarkan faktor kontingensi dalam membantu organisasi di Malaysia memilih alat dan teknik lean yang tepat berdasarkan konteksnya. Sebilangan besar kajian terdahulu didapati memfokuskan pada pemilihan alat lean tetapi mengambilkira faktor kontingensi kritikal yang dapat mempengaruhi pemilihan alat dan teknik lean tersebut. Selain itu, didapati tidak ada kajian yang serupa mengenai pemilihan alat dan teknik lean dalam konteks Malaysia. Alat dan teknik lean yang betul untuk digunakan mungkin berbeza-beza bergantung pada beberapa faktor, oleh itu untuk mengelak daripada pembaziran dan ketidakpuasan yang tidak perlu, lebih baik organisasi memilih alat dan teknik lean yang sesuai dengan keadaan organisasi agar dapat memberi manfaat kepada organisasi tersebut. Kajian ini menggunakan kaedah mod-campuran, secara eksklusifnya berfokus kepada pembangunan, penilaian, dan penyempurnaan instrumen yang dibangunkan atau secara khusus dikenal sebagai "*DEALS*". Instrumen ini, menggabungkan 10 alat dan teknik lean yang paling banyak organisasi di Malaysia. Instrument ini menekankan penggunaan proses secara holistik di mana bermula dari mendiagnosis keadaan semasa sisa di organisasi sehingga panduan memilih alat dan teknik lean yang sesuai dengan mengambilkira faktor-faktor luar jangka yang mempengaruhi pemilihan alat dan teknik lean, seperti keupayaan mendapatkan sokongan dan komitmen dari pihak pengurusan atasan dan faedah yang diperolehi setelah melaksanakan alat lean yang dipilih. Dua kaedah pemilihan digunakan, iaitu (1) *Simple Additive Weighted (SAW)* bagi pemilihan asas dan (2) *Analytical Hierarchical Process (AHP)* bagi pemilihan yang lebih terperinci. Berdasarkan hasil penilaian, semua responden (100%) bersetuju ciri-ciri instrument yang dibangunkan seperti kebolehgunaan, ketepatan, kesesuaian dan kesahihan pilihan. Hasil akhir pengesahan juga menunjukkan kesalahan kurang dari 5% dengan pembandingan

bersama dengan dua perisian dipasaran iaitu perisian *Expert Choice 11* dan perisian *Superdecision*. Dengan adanya *DEALS* ini, diharapkan dapat memberi manfaat yang pengurus besar pengurus organisasi, eksekutif, perunding, penyelidik, dan ahli akademik sebagai instrumen sokongan dalam membantu memilih alat dan teknik lean dan secara umumnya dapat melahirkan pekerja yang berpengetahuan di dalam organisasi.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Fundamentally, organisations need to fulfil the needs and demands of all relevant stakeholders (e.g. customers, employees, shareholders, supply chain partners, and communities) in order to remain competitive and relevant in this unpredictable market [1]–[6]. The growing demands for high-quality products and services within a shorter period of time at lower cost have highlighted the need for the organisations to constantly improve their performance. Therefore, organisations need to efficiently and effectively identify the best approach in terms of time and cost without compromising their commitments and circumstances.

Some of the key operational methodologies for organisations to increase and maintain their playing point in the global business market involve incremental redesigning and development [7]–[9], which highlight the significance of implementing "improvement initiatives" at the organisational level. Examples of improvement initiatives (in the forms of approaches, systems, tools, and/or techniques) include business process re-engineering, environmental management system, lean production, six sigma, and product life cycle management [3], [10].

In this study lean production was selected to be focused on the selection of appropriate lean tools and techniques. The increasing number of lean tools and techniques in the market for selection has become a challenge for numerous organisations [11]–[16]. Moreover, adequate time, financial capability, and knowledge are necessary for organisations to select the most beneficial and appropriate lean tools and techniques [3], [17]–[19] according to the organisational goals, available resources, and circumstances.

Furthermore, there is no single lean tools and techniques that can holistically address all issues within an organisation [3], [15], [17], [20], [21], as each lean tools and techniques has its own strengths and limitations and can differently influence the performance of the organisation [22]. There are various aspects that influence the selection of the appropriate lean tools and techniques, such as staff competence, areas in need of improvement, and organisational size and age [3, 15, 16].

The need of lean tools and techniques in waste elimination or reduction can be seen in several studies and the research interest to lean tools and techniques is at the increasing trend. It tallies with the searching results by using keyword "lean tools" in Science Direct search engine by filtering publication in 2010 to 2020 as shown in figure 1.1. It shows that, lean tools are very significant field to be explored by focusing on different perspectives.

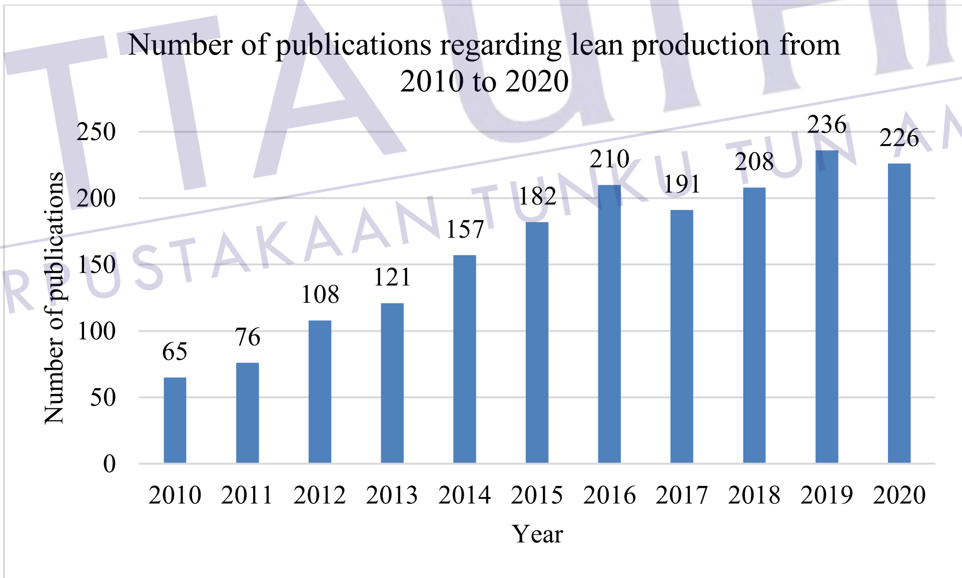

Figure 1.1: Number of publications using keyword lean tools in 2010-2020

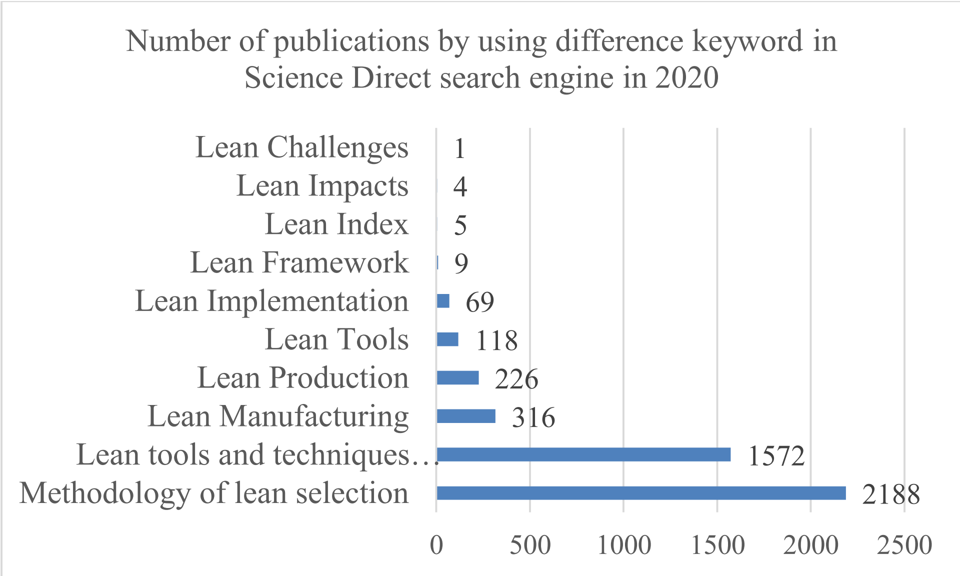

Figure 1.2: Number of publications by using difference keyword in Science Direct search engine in 2020

Figure 1.2 shows that, by using few keywords downloaded on January 2021, there is a huge number of documents found the Science Direct search engine. When arranging the number of documents, it shows that keyword of methodology of lean selection is the highest number of publications followed by the lean tools and techniques selection and others.

In view of the above, the current study very significant to be explored and exclusively focused on the following lean tools and techniques selection based on interview with lean experts: (1) 5S; (2) cellular manufacturing (CM); (3) Kaizen; (4) poka-yoke (mistake proofing); (5) standardised work; (6) value stream mapping (VSM); (7) Jidoka; (8) Kanban; (9) plan-do-check-act (PDCA); (10) total productive maintenance (TPM).

1.2 Problem Statement

Most organizations face difficulties to select appropriate lean tools and techniques due to numerous tools available [11]. Current studies show that, there are more than 50 lean tools and techniques that are widely used, depending on the size of the industries such as 5S, Kanban, Kaizen, Cellular Manufacturing, Value Stream Mapping and others [25]. In Malaysia, various studies were found related to lean production tools and techniques adoption and implementation especially in automotive [26]–[28], electrical and electronic [29] and food and beverage industries [30] in order to achieve higher performance improvement. Each lean tools and techniques also has its own purpose, strengths and limitations. There is no one best lean tools and techniques that can solve all organisational problems [3], [31]. The most appropriate lean tools and techniques selection depends on the context or factors in which it is adopted. Selection and implementation of lean tools & techniques also required time, resources, financial and knowledge [3], [31]. Therefore, to keep away from unnecessary waste and dissatisfaction, it would be better for organizations to choose the right lean tools that will fit with organization's situation such as availability of resources and others and give benefits to the organization.

However, to date, the selection of lean tools and techniques using a rational decision-making process within the Malaysian context has been less explored. Focusing on that, this study aimed to develop a decision support instrument for the selection of appropriate lean tools and techniques using simple additive weighting (SAW) for basic selection and Analytical Hierarchical Process (AHP) for more advanced selection.

1.3 Aim and Objectives of the Research

The general aim of this study was to develop a decision support instrument for the selection of appropriate lean tools and techniques. The specific objectives of this study are as follows:

i. To identify the critical contingency factors that influence the selection of lean tools and techniques.
ii. To explore the currently available decision support instruments for the selection of lean tools and techniques.
iii. To propose and evaluate a decision support instrument for the selection of lean tools and techniques.
iv. To validate the proposed decision support instrument with the existing established software.

1.4 Scope of the study

Firstly, this study exclusively focused on 10 main lean tools and techniques that are widely used in the Malaysian manufacturing sector because of the technical constrains. Secondly, the selection of appropriate lean tools and techniques in this study was performed, with the inclusion of 10 contingency factors that influence the selection. With respect to the objectives of this study, the rational decision making of selecting appropriate lean tools and techniques was explored, which did not include the adoption and maintenance of lean tools and techniques. Additionally, the development of the proposed decision support instrument in this study specifically made use of both SAW (for basic selection) and AHP (for more advanced selection).

1.5 Research Questions

With respect to the objectives of this study, the following research questions were addressed:

i) What are the critical contingency factors that influence the selection of lean tools and technique?
ii) What are the currently available decision support instruments for the selection of lean tools and techniques?
iii) What are the strengths and limitations of the currently available decision support instruments?
iv) What are the strengths and limitations of the proposed decision support instrument in this study?
v) How are the design, steps, and content of the proposed decision support instrument?
vi) How can the proposed decision support instrument be improved?
vii) How does the proposed decision support instrument perform against other decision support instruments available in the market?

1.6 Significance of the research

The need to select appropriate lean tools and techniques was deemed significant due to several reasons. Firstly, the selection of appropriate lean tools and techniques can prevent any wastage of resources and guarantee satisfaction in terms of organisational performance considering the extensive amount of time and resources (e.g. financial resources and knowledge) involved in determining appropriate improvement initiatives for implementation [3], [17]. Secondly, the number of available lean tools and techniques continue to increase annually. With the wide availability of these tools and techniques in the market, organisations need a reliable and valid decision-making aid or support to select appropriate lean tools and techniques [3], [17] according to the existing organisational contexts and circumstances [3], [32]–[34]. However, only a few prior studies focused on the selection of lean tools and techniques [3], [17], particularly within the Malaysian context, which highlighted the significance of the current study.

1.7 Thesis Outline

As illustrated in Figure 1.1, this thesis consists of six chapters, which are organised as follows:

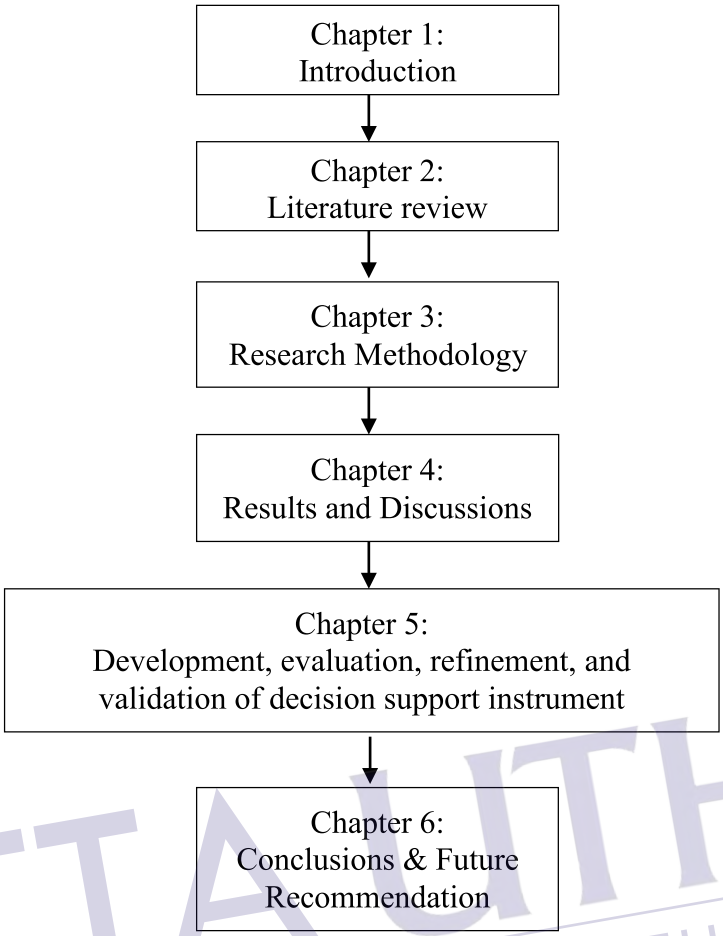

Figure 1.3: Thesis Outline

Firstly, Chapter 1 presented the background of study and problem statement. This chapter also described the objectives of this study as well as the scope and significance of this study.

Following that, Chapter 2 reviews relevant literature on lean production and its principles as well as common lean tools and techniques. Apart from the types of wastes in different manufacturing organisations, this chapter also includes the discussion of the rational decision making using SAW and AHP. Besides that, this chapter also reviews the contingency factors that influence the selection of lean tools and techniques. In addition, this chapter reviews prior studies on the selection of lean tools and techniques to aid the development of a decision support instrument for manufacturing organisations.

Chapter 3 specifically describes the employed research design and data collection in this study. In particular, this chapter justifies the adopted methods in the different stages of this study. Besides that, this chapter also describes the validation of the developed decision support instrument in this study.

Meanwhile, Chapter 4 presents the demographic profile of the survey respondents and discusses the obtained results of the exploratory survey. This chapter also presents the results of the semi-structured interviews. The results specifically include the profile of interviewees, interview findings, key factors of the selection of appropriate lean tools and techniques, and the types of waste versus lean tools and techniques based on the interviewees' experiences also had been discussed.

In addition, Chapter 5 discusses the development, evaluation, refinement, and validation of a decision support instrument in selecting appropriate lean tools and techniques. Apart from that, this chapter also presents the interface of decision support instrument that incorporates both SAW and AHP. Basically, the proposed decision support instrument was developed, evaluated, refined, and validated as a decision-making tool in this study for the manufacturing organisations to select appropriate lean tools and techniques based on their available resources and constraints.

Last but not least, Chapter 6 is the final chapter that presents the summary of main findings with respect to the objectives of this study. This chapter also describes the contributions and limitations of this study. Several recommendations for future research are also presented in this final chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews relevant literature on lean tools and techniques. This chapter first introduces lean production and its principles, which also include some of the most widely used lean tools and techniques across industries. Following that, this chapter also includes the discussion of the rational decision making using SAW and AHP. In addition, this chapter presents a comprehensive review of prior studies on the selection of lean tools and techniques. A chapter summary is presented at the end of this chapter.

2.2 Lean production

Taiichi Ohno and Shigeo Shingo from Toyota Motor Corporation, Japan first introduced “Toyota Production System” (TPS) and coined the term “lean production” (or “lean manufacturing”) back in the late 1980s [35], [36].

The concept of lean production has gained global recognition as an essential practice for manufacturing organisations. In general, lean production describes an approach that encourages the execution of specific practices with the aims of reducing waste and enhancing work performance [37]. Unlike the conventional mass production approach, the implementation of lean production approaches is broadly perceived to be more cost- and time-effective [38].

Lean production emphasises optimising the consumption of resources by eliminating or minimising waste in the production or manufacturing process. Table 2.1 describes seven types of waste that are perceived as non-added value activities: (1)

overproduction; (2) waiting time; (3) transportation; (4) inventory; (5) inappropriate processing; (6) excess motion; (7) product defects [35], [39], [40]. Examples of lean tools and techniques include 5S, cellular layout, just-in-time (JIT), Kanban, Kaizen, pull production system, single minute exchange of dies (SMED), total quality management (TQM), and value stream mapping (VSM) [41], [42]. With the appropriate lean tools and techniques, enhanced work performance (e.g. high-quality outcomes, optimised usage of resources, and shorter operational time) and even better financial performance are expected.

Table 2.1 The description of seven types of waste [43]

No	Type of waste	Description
1	Over production	-Product made for no specific customer -Development of a product, a process or a manufacturing facility for no additional value.
2	Waiting	As people, equipment or product waits to be processed it is not adding any value to the customer.
3	Transport	-Moving the product to several locations -Whilst the product is in motion it is not being processed and therefore not adding value to the customer.
4	Inventory	Storage of products, intermediates, raw materials, and so on, all costs money
5	Over processing	When a particular process step does not add value to the product.
6	Motion	-The excessive movement of the people who operate the manufacturing facility is wasteful. Whilst they are in motion they cannot support the processing of the product -Excessive movement of data, decisions and information.
7	Defects	Errors during the process either requiring re-work or additional work.

2.3 Lean Production Principles

TPS introduces the concept of lean thinking (LT), where value-added activities and non-added value activities are distinguished to ensure every process or step adds value. TPS is a unique approach that aims to minimise waste in production or manufacturing. It emphasises the significance of adding value to the organisation at lower cost by eliminating waste. JIT and Jidoka, which are represented by two main pillars in the construction of the "House of TPS" (Figure 2.1), establish the underlying basis of TPS [43].

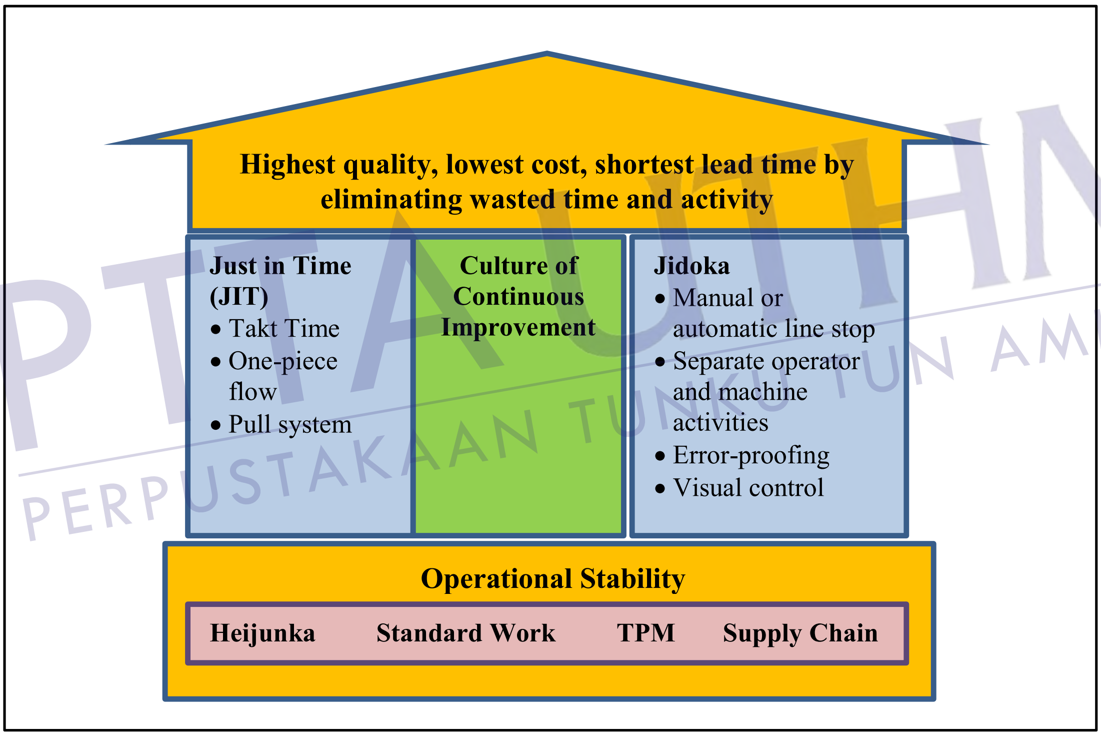

Figure 2.1: 'House of TPS' [43]

In particular, JIT involves a continuous series of processes that produce what is needed for the next process with the aim of minimising inventories in every part of the plant and reducing the setup time [44]. Apart from reduced inventories and lower setup time, the implementation of JIT can improve quality, customer service, employee skills, and overall productivity and profitability [45]. The concept of JIT involves several components, namely Kanban, waste removal, takt time, SMED, and VSM.

Meanwhile, Jidoka is a method of converging problems. Jidoka describes the need to prevent defects and damage to the products and emphasises methods to prevent any damage to the equipment or machine in the production or manufacturing, as any equipment or machinery problem will interrupt the overall process from running smoothly. Jidoka is synonymous with autonomous human touch sensing, which often involves high-tech sensing equipment. Basically, a Jidoka system is set to prevent any damage and initiate immediate response to quickly resolve any detected problem in order to ensure an uninterrupted process of production and manufacturing. The concept of Jidoka involves several components, namely 5S, poka-yoke, and visual control.

In lean production, achieving a lean expenditure by a rapid flow is the primary goal, and the elimination of waste and disruptions and the development of a flexible system are the supplementary goals [46]. As shown in Figure 2.2, the building blocks of a lean system consists of four key components, which are (1) product design, (2) process design, (3) personnel elements, and (4) manufacturing planning.

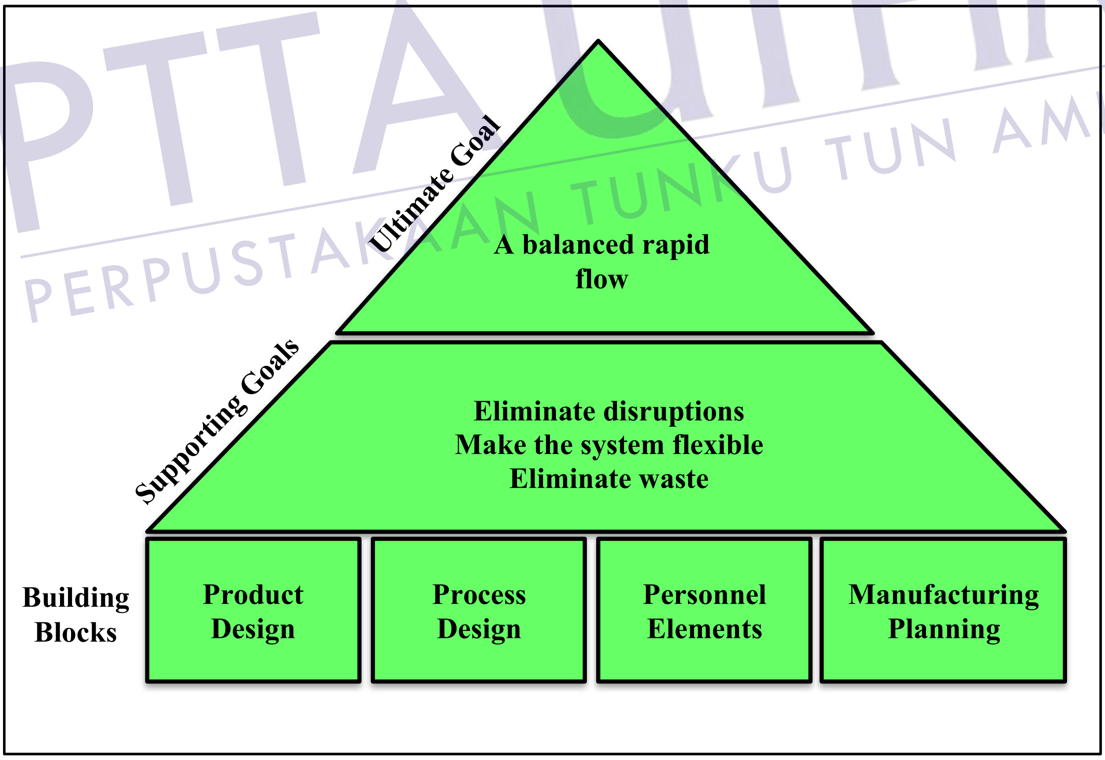

Figure 2.2: Lean system by Stevenson (2012) [46]

2.4 Lean production Tools and Techniques

Numerous lean tools and techniques are available for industries or organisations of different sizes. As presented in Table 2.2, more than 50 lean tools and techniques are available for execution across industries [30], [47], [48]. For instance, Matt and Rauch [48] grouped a total of 37 lean tools and techniques that are widely used in Italy. Meanwhile, there are 30 lean tools and techniques used in India [47]. There are 18 lean tools and techniques that are available and widely used across automotive, electrical, and electronics organisations in Malaysia [30].

Table 2.2: List of lean production tools and techniques widely used by industries for the past ten years, 2010 – 2020.

No	Lean Production Tools & Techniques	[48]	[47]	[30]
		Italy	India	Malaysia
1	5S	√	√	√
2	Cellular Manufacturing (Cell Layout)	√	√	√
3	Kaizen	√	√	√
4	Poka-yoke (Mistake proofing)	√	√	√
5	Setup Time Reduction (SMED)	√	√	√
6	Standardization	√	√	√
7	Value Stream Mapping (VSM)	√	√	√
8	Jidoka (Zero Defect)	√	√	√
9	Autonomation	√	√	
10	Overall Equipment Effectiveness (OEE)	√	√	
11	Quality Function Deployment (QFD)	√	√	
12	Statistical Process Control (SPC)	√	√	
13	Andon (Lighting Signal)			√
14	Group Technology			√
15	Heijunka			√
16	Just in Time	√		√
17	Kanban		√	√

Table 2.2: List of lean production tools and techniques widely used by industries for the past ten years, 2010 – 2020. (Continue)

No	Lean Production Tools & Techniques	[48]	[47]	[30]
		Italy	India	Malaysia
18	One piece flow	√		√
19	Plan Do Check Act (PDCA)			√
20	Root Cause Analysis			√
21	Takt Time		√	√
22	Total Productive Maintenance (TPM)	√		√
23	5 Whys		√	
24	8 Steps Practical Problem Solving (PPS) Method		√	
25	Analysis of Variance (ANOVA)		√	
26	Autonomous work groups	√		
27	Benchmarking	√		
28	Continuous Flow		√	
29	Continuous Improvement		√	
30	Design for Six Sigma (DFSS)		√	
31	Economic (optimal) lot size	√		
32	Elimination of Waste		√	
33	Failure Mode Efffect Analysis (FMEA)	√		
34	First in first out (FIFO)	√		
35	Fishbone Diagrams		√	
36	Idea Management	√		
37	Job rotation	√		
38	Just in Sequence	√		
39	Lean Office (Administration)	√		
40	Line Balancing and Muda Reduction	√		
41	Milkrun	√		
42	Optimization of the supply chain	√		

Table 2.2: List of lean production tools and techniques widely used by industries for the past ten years, 2010 – 2020. (Continue)

No	Lean Production Tools & Techniques	[48]	[47]	[30]
		Italy	India	Malaysia
43	Pareto Analysis		√	
44	PPS Simulation software	√		
45	Preventive maintenance	√		
46	Process Mapping		√	
47	Production Leveling		√	
48	Quality Circles	√		
49	Quick & Easy Kaizen		√	
50	Simulation software	√		
51	Supplier Development	√		
52	Visual Controls		√	
53	Visual Management	√		
54	Voice of Customer (VOC)		√	
55	Work Simplification		√	
56	Work station design	√		

Figure 2.3 shows the analogy of filtration process for lean tools and techniques selection. For the current study, a comprehensive review of related literature revealed a total of 56 most commonly used lean tools and techniques in the market as shown in table 2.2 before. Based on the priority of implementation across different countries, including Malaysia by considering 2 out of 3 countries, a total of 22 lean tools and techniques were identified. However, due to the technical constraint for this study, the expert opinion method was performed, where by 3 experts was selected based on their expertise in consulting varies industries in Malaysia in implementing lean. From 22 lean tools and techniques, these experts have shortlisted the most popular lean tools and techniques among Malaysian organisations resulting in the final selection of 10 most commonly used lean tools and techniques: (1) 5S; (2) cellular manufacturing (CM); (3) Kaizen; (4) poka-yoke (mistake proofing); (5) standardised work; (6) value stream mapping (VSM); (7) Jidoka; (8) Kanban; (9) plan-do-check-act (PDCA); (10) total productive maintenance (TPM).

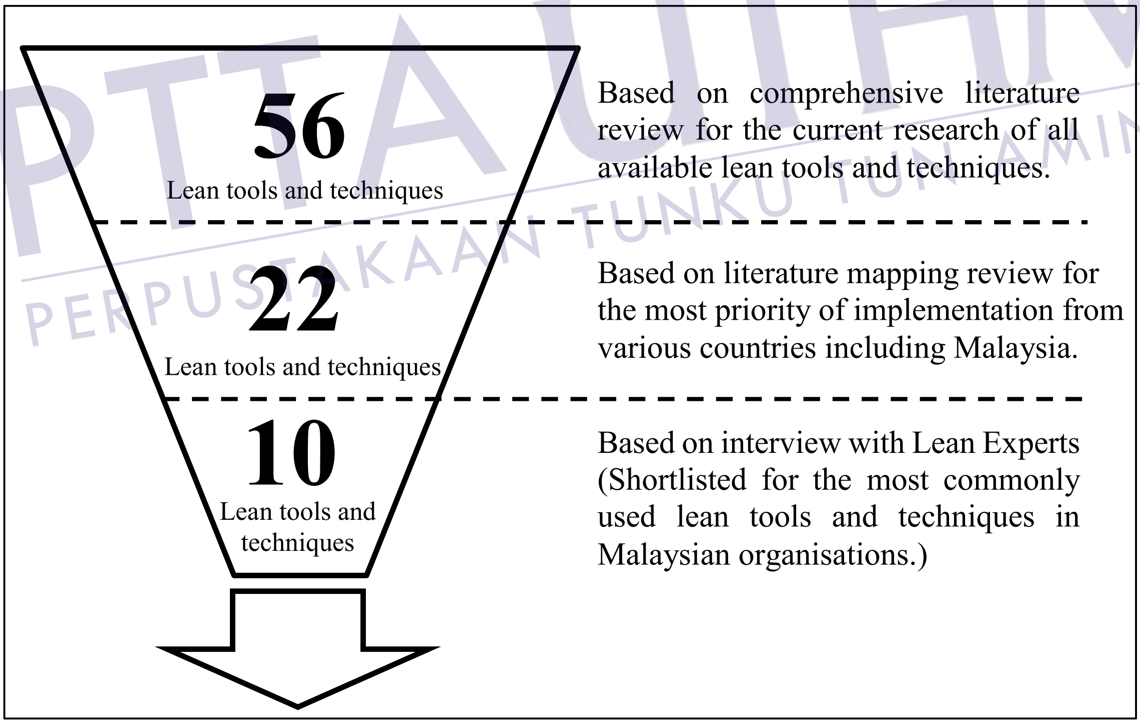

Figure 2.3: Analogy of filtration process of lean tools and techniques selection

2.4.1 5S (Sort, Setting, Shine, Standardise, Sustain) System

One of the most popular lean manufacturing practices is the 5S. Through the 5S system, organisations can enhance their overall performance in terms of operating cost, productivity, lead time, equipment performance, work space quality, and delivery time [49]. In general, the 5S system involves five specific steps [41]. Firstly, the first step (**Sort**) involves creating an uncluttered and orderly work space, which includes organising all equipment, materials, and tools and putting away unnecessary items that can adversely affect work productivity.

The second step (**Setting**) involves creating a systematic order of items and activities at work for an efficient work flow. For instance, every item is clearly labelled and placed in a systematic order. The items and activities at work are purposefully organised based on the following criteria: (1) items are properly labelled and stored with visual confirmation; (2) items that are frequently used are placed in close proximity; (3) items are arranged and stored visibly to minimise the need to open and close the drawers or storage containers; (4) work guidelines are often updated and presented at the work station; (5) ergonomic guidelines are incorporated into the work and tool design; (6) key indicators and information boards as well as production goals and status (e.g. inventory, training, and calibration) are displayed to provide clear guidelines to all employees.

The third step (**Shine**) in the 5S system involves restoring the work station to its orderly and organised state at the end of the working day or work shift through a systematic cleaning approach. Appointed representatives come up with a specific cleaning approach (e.g. tools and checklists) and examine the outcomes periodically. Most importantly, these daily tasks should be routinely executed. This step ensures that all items are placed and stored accordingly for the next use at any time.

The next step (**Standardise**) in the 5S system ensures that all employees maintain the first three steps as part of their daily routine at the workplace. The work details are formulated as work regulations that include procedures and checklists, which are displayed at every work station after the first three steps are established.

The final step (**Sustain**) ensures the execution of a new organisational routine and culture after the first four steps are established. In this step, the organisation sustains the first four steps and does not revert to its prior routine.

2.4.2 Cellular Manufacturing (CM)

A production layout is an approach of coordinating the physical formation of a production facility according to a series of production steps [42]. The physical formation of such facility that allows a smooth process flow can be established through a lean operation [50]. In this case, cellular manufacturing (CM) is a single process that involves organising all equipment and workstations in a specific, purposeful order for a smooth operation with minimal interruption and transport [51]. Designing CM mainly aims to form part cells, determine part families, and assign part families to the corresponding machine cells for minimal intercellular movement. CM involves clustering equipment and machinery according to the required process [52]. CM minimises non-added value activities, such as unnecessary transportation and motions of machinery, materials, and workers [51]. Based on a sample of 70 manufacturing organisations in a prior study, the survey results revealed that the execution of CM can reduce setup time, work-in-process inventory, material handling cost, and labour cost as well as increase the quality and material flow [52].

2.4.3 Kaizen

Kaizen or also known as continuous improvement (CI) refers to improvement initiatives that enhance success and minimise failure [53]. CI is important for organisations to remain competitive in this market. In general, CI reflects the underlying need for quality and worth; in this case, the organisation has to believe the value of its long-term effort [54]. CI emphasises the management-driven factor that propels organisational change. Effective strategies are executed to address the identified causes of inefficiency at the workplace that are determined using CI tools. A committed workforce, equipped with organisational knowledge base, is established to eliminate the identified waste (e.g. idle time, unnecessary waiting time, or issues related to inventory or resources) in a process with zero inventories. There are different aspects that influence the success of CI, such as adaptation, employee perception, implemented initiative, leader engagement, motivation, team work, and training. Examples of CI mechanisms include problem-solving process, training tools and techniques, development of idea management, and development of a reward and recognition system [55]–[57].

2.4.4 Poka-Yoke (Mistake Proofing)

Singo developed poka yoke as an autonomous defect control system in a machine that examines all parts to ensure zero defects. Poka-yoke, which is also referred to as mistake-proofing, aims to prevent the occurrence of errors or the adverse implications of errors through specific process and design features [58]. Through poka-yoke, the cause of any identified defective part is determined at source to prevent the transfer of the defective part to the next workstation [59].

2.4.5 Standardized Work

Standardised work refers to value-added activities that go by the standard guidelines at the workplace. A lean management mainly aims to minimise variability (e.g. demand variability, manufacturing variability, and supplier variability) at every chance. In this case, manufacturing variability involves inconsistency in the properties and features of the products as well as production time that include downtime, absenteeism, or competence of workers. The steps involved in standardised work include process mapping, operator loading, and any approaches to minimise inconsistency at source [60]. Standardised work is particularly beneficial to improve the overall cost and quality of products when complex work activities are involved.

2.4.6 Value Stream Mapping (VSM)

Value stream mapping (VSM) involves mapping the flows of the required materials and information to organise the work details of manufacturers, suppliers, and distributors in order to deliver the products to customers. In VSM, the identified source of waste and the opportunity to execute lean tools and techniques are first mapped, which produces a current state map. The visual representation helps to facilitate the identification of value-added activities in a value stream and removal of non-added value activities [61]. After the initial mapping, the next step in VSM involves mapping a future state map based on the proposed improvement initiatives. It serves to reaffirm the decision of implementing lean tools and techniques and subsequently, encourage the actual implementation of the improvement initiatives in order to achieve the anticipated outcomes. The details of the inventory, production time (e.g. process time, lead time, and waiting time), and the process flow (to solve the bottleneck cycle time against takt time) are clearly presented in VSM. An organised improvement initiative is executed from the bottleneck area. However, it is not possible to predict the variation in the inventory levels across different circumstances in the production process by observing a future state map (a static map), which highlights the need for a simulation tool [62]. Fawaz et al. [63] developed a simulation model of “before” and “after” scenarios, which revealed lower production lead time and work-in-process inventory and suggested the utilisation of a simulation model to examine the performance measures prior to the lean implementation.

2.4.7 Jidoka

Jidoka improves the quality of the production process and its product through specific practices, which include autonomation and mistake-proofing [64]. Jidoka can be seen as a design equipment that initiates partial automation of the manufacturing process and terminates the manufacturing process in the case of any defects [65]. With that, multiple work stations can be simultaneously monitored for various aspects of quality, resulting in lower labour cost and higher work quality.

2.4.8 Kanban

Taiichi Onho first developed Kanban (which means “card” or “visible”) to manage the production process and execute JIT manufacturing at Japan’s Toyota manufacturing plants. Basically, Kanban refers to a signalling card that contains details of the quantity, origin, and destination of the product. Through Kanban, the handling of materials and management of the inventory can be simplified. A small quantity of materials are made available at the point of usage and restored when Kanban is issued, instead of accumulating the materials in a large quantity at the production line [66].

The execution of Kanban proposes a pull environment at the organisational level, in which products are produced based on the data of consumed products, not the projected data.

Basically, Kanban is implemented to produce products based on the signal issued by customers or to restore the consumed products. The implementation of Kanban helps the Toyota manufacturing plants to lower work in progress (WIP) and inventory holding cost [67]. Besides that, other benefits of implementing Kanban include lower inventory and overproduction and improved production flow, responsiveness to demand changes, and ability to manage the supply chain [66], resulting in enhanced performance metrics (e.g. overall organisational cost, delivery time, and flexibility).

2.4.9 Plan-Do-Check-Act (PDCA)

Another basic lean tool or technique that is globally recognised and widely used in numerous organisations is the plan-do-check-act (PDCA) cycle or Deming circle, which was introduced by William Edwards Deming in 1950 [68]. Figure 2.4 illustrates the PDCA cycle.

As compared to the "right first time" strategy, the implementation of PDCA is deemed more effective in terms of performing and managing a task. PDCA promotes a constant search for improved actions. There are two forms of corrective actions in PDCA, which are temporary and permanent corrective actions. In particular, a temporary corrective action incorporates only essential step to address and resolve the identified issue whereas a permanent corrective action focuses on a thorough research to remove the root problem and sustain the improved state after correction [68].

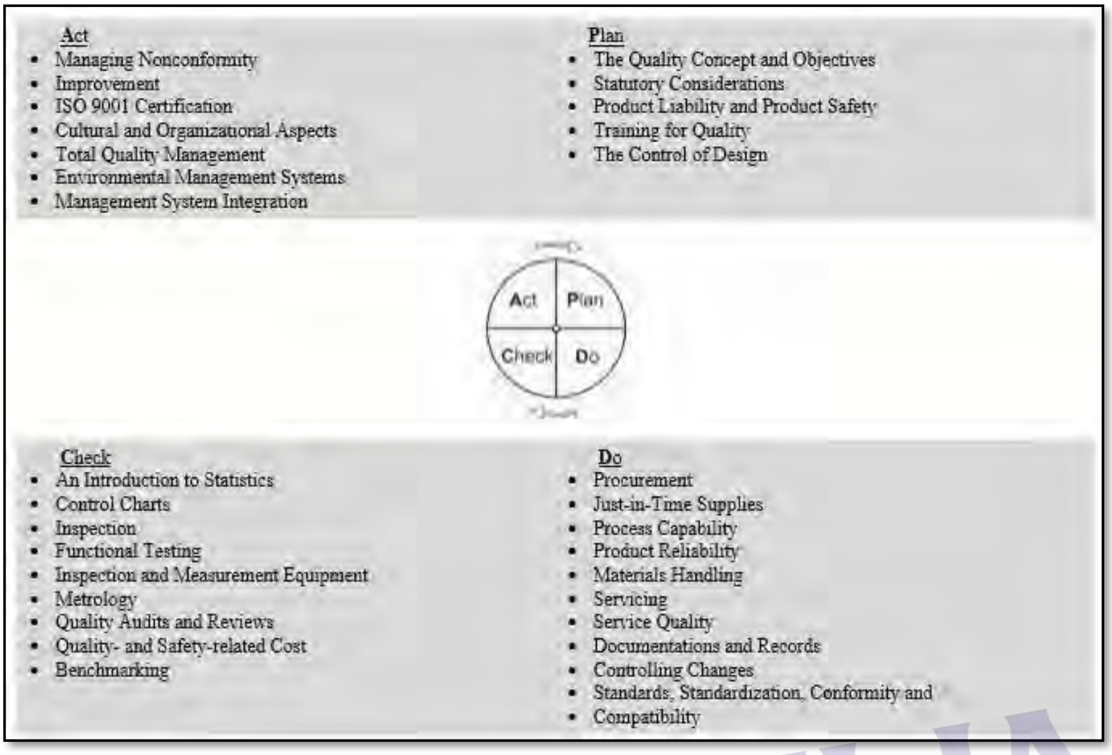

Figure 2.4: PDCA cycle [68]

2.4.10 Total Productive Maintenance

Total productive maintenance (TPM) refers to an initiative that involves machine operators for a continuous and efficient use of equipment and machinery [69]. Focusing on minimising the occurrence of equipment breakdowns, defects, and safety problems [70], TPM establishes the underlying basis of lean maintenance and safety [71]. It incorporates innovative management strategies and various characteristics of productive and predictive maintenance [72].

TPM emphasises the reliability and effectiveness of manufacturing equipment throughout its operating lifespan [71] based on an inclusive productive maintenance system with the involvement of workers at all levels (from top management to daily employees). Basically, it ensures periodic maintenance for equipment and machinery. The involvement of workers is the essence of the TPM, in which the top management supports and prompts workers to effectively operate and maintain the equipment and machinery with care [71]. TPM contributes significant improvements in terms of (lower) failure time, availability of equipment and machine, safety measures, and product and work quality [71].

2.5 Rational Decision making

Studies have stressed the significance of making rational decisions in the selection and implementation of appropriate improvement initiatives [3], [73]–[76]. Rational decision making refers to a logical expectation of achieving the best possible outcome based on an accurate assessment of the relevant values and risk preferences [77]. A rational selection of appropriate improvement initiatives is linked to a systematic process that is specifically designed according to the organisational goals [78]. Accordingly, a decision is selected from a list of possible decisions based on multiple criteria. Making an appropriate decision to achieve the best possible solution is a challenge.

Addressing that, multiple attribute decision making (MADM) technique, which is a part of multiple criteria decision making (MCDM) technique [79], is introduced. MADM refers to evaluating, prioritising, and selecting an option from the available “alternatives” of different “attributes”. In MADM, the relative importance of each attribute is typically organised according to an ordinal or a basic scale, while the problem is expressed in a matrix format that incorporates all possible “attributes” (columns) and competing “alternatives” (rows). In particular, the term “alternative” refers to action, candidate, option, or policy [79], while the term “attribute” refers to goals or criteria. The attributes of the available alternatives are filtered or ranked for selection [79].

The MADM technique can be incorporated into various methods, such as weighted sum model (WSM) or simple additive weighting (SAW), weighted product model (WPM), technique for order preference by similarity to ideal solution (TOPSIS), and analytic hierarchy process (AHP). Table 2.3 presents the benefits and drawbacks of each method.

Table 2.3: The strength and weakness of each MADM [80]

Methods	Strength	Weakness
Analytic Hierarchy Process (AHP)	Easy to use; scalable; hierarchy structure can easily adjust to fit many sized problems; not data intensive.	Problems due to interdependence between criteria and alternatives; can lead to inconsistencies between judgment and ranking criteria; rank reversal.
Technique for Order Preferences by Similarity to Ideal Solutions (TOPSIS)	Has a simple process; easy to use and program; the number of steps remains the same regardless of the number of attributes.	Its use of Euclidean Distance does not consider the correlation of attributes; difficult to weight and keep consistency of judgment.
Simple Additive Weighting (SAW)	Ability to compensate among criteria; intuitive to decision makers; calculation is simple does not require complex computer programs.	Estimates revealed do not always reflect the real situation; result obtained may not be logical.
Weighted Product method (WPM)	Eliminate any unit of measure; thus, can be used in single and multi- dimensional MCDM. Instead of actual values, it can use relative ones.	No solution with equal weight of decision matrices.

Therefore, for the current study, both SAW and AHP were considered, as these methods. SAW was chosen because this method is simple and commonly used in research such as in energy management decision [81], location planning [82] and others. The former does not involve complex computer programmes, which makes it suitable for making simple selections. Meanwhile, AHP was chosen because this method also commonly used in currently research such as [83]–[87]. This method involves a more comprehensive approach that calculates the inconsistency ratio to screen the inconsistency rating in user judgement for optimised outcomes.

REFERENCES

[1] K. J. Foley, "Third Generation Quality Management: From Atoms to Bits, or Quality Management in the Knowledge Society," in *International Conference in Quality Management*, 2010.

[2] H. J. Harrington, "Continuous versus breakthrough improvement: Finding the right answer," *Bus. Process Re-engineering Manag. J.*, vol. 1, no. 3, pp. 31–49, 1995.

[3] M. Mohammad, "Development of a guidance model for the selection of organisational improvement initiatives.," Massey University, Palmerston North, 2012.

[4] N. Slack, S. Chambers, R. Johnston, and A. Betts, *Operations and Process Management: Principles and Practice for Strategic Impact*, 2nd ed., vol. null. Prentice Hall, 2009.

[5] V. Ramakrishnan, J. Jayaprakash, C. Elanchezhian, and B. Vijaya Ramnath, "Implementation of Lean Manufacturing in Indian SMEs-A case study," *Mater. Today Proc.*, vol. 16, pp. 1244–1250, 2019, doi: https://doi.org/10.1016/j.matpr.2019.05.221.

[6] P. Tiwari, J. K. Sadeghi, and C. Eseonu, "A sustainable lean production framework with a case implementation: Practice-based view theory," *J. Clean. Prod.*, vol. 277, p. 123078, 2020, doi: https://doi.org/10.1016/j.jclepro.2020.123078.

[7] M. Hammer, "Grounding strategy in reality," *European Business Forum*, 2005.

[8] P. D. I. Sohal, *TQM and innovation: a literature review and research framework*, 21st ed. 2001.

[9] K. D. Swinehart, P. E. Miller, and C. Hiranyavasit, *World-class manufacturing: Strategies for continuous improvement*, 25(1/2). 2000.

[10] A. Van der Wiele, A. R. T. Williams, and B. G. Dale, "ISO 9000 series registration to business excellence: the migratory path," *Bus. Process Manag. J.*, vol. 6, no. 5, pp. 417–427, 2000.

[11] H. J. Harrington and K. C. Lomax, *Performance improvement methods: Fighting the war on waste*. New York, NY: McGraw-Hill, 2000.

[12] L. F. Baxter and A. M. MacLeod, *Managing performance improvement*. New York, NY: Routledge, 2008.

[13] T. H. Davenport, L. Prusak, and H. J. Wilson, "What's the big idea? Creating and capitalizing on the best management thinking.," *Boston: Harvard Business School Press*, 2003.

[14] S. Gupta, S. Kapil, and M. Sharma, "Improvement of laboratory turnaround time using lean methodology," *Int. J. Health Care Qual. Assur.*, vol. 31, no. 4, pp. 295–308, Apr. 2018, doi: 10.1108/IJHCQA-08-2016-0116.

[15] F. Aqlan and L. Al-Fandi, "Prioritizing process improvement initiatives in manufacturing environments," *Int. J. Prod. Econ.*, vol. 196, pp. 261–268, 2018, doi: https://doi.org/10.1016/j.ijpe.2017.12.004.

[16] H. Kohl, W. Schliephack, and B. Muschard, "Increasing challenges for sustainability for manufacturing industry based on global, national and technological initiatives," *Procedia Manuf.*, vol. 43, pp. 293–298, 2020, doi: https://doi.org/10.1016/j.promfg.2020.02.160.

[17] N. Thawesaengskulthai, "Selecting quality management and improvement initiatives: Case studies of industries in Thailand," University of Nottingham, 2007.

[18] J. Ukko, M. Nasiri, M. Saunila, and T. Rantala, "Sustainability strategy as a moderator in the relationship between digital business strategy and financial performance," *J. Clean. Prod.*, vol. 236, p. 117626, 2019, doi: https://doi.org/10.1016/j.jclepro.2019.117626.

[19] K. Rudnik, G. Bocewicz, A. Kucińska-Landwójtowicz, and I. D. Czabak-Górska, "Ordered fuzzy WASPAS method for selection of improvement projects," *Expert Syst. Appl.*, p. 114471, 2020, doi: https://doi.org/10.1016/j.eswa.2020.114471.

[20] O. M. Ikumapayi, S. T. Oyinbo, E. T. Akinlabi, and N. Madushele, "Overview of recent advancement in globalization and outsourcing initiatives in manufacturing systems," *Mater. Today Proc.*, vol. 26, pp. 1532–1539, 2020, doi: https://doi.org/10.1016/j.matpr.2020.02.315.

[21] N. Thawesaengskulthai, J. D. . T. T. Tannock, N. and T. Thawesaengskulthai J. D. T., N. Thawesaengskulthai, and J. D. . T. T. Tannock, "A decision aid for selecting improvement methodologies," *Int. J. Prod. Res.*, vol. 46, no. 23, pp. 6721–6737, Dec. 2008, doi: 10.1080/00207540802230553.

[22] F. Francis, "One hundred to one," *Qual. World*, vol. 36, no. 1, pp. 26–31, 2010.

[23] P. G. Benson, J. V Saraph, and R. G. Schroeder, "The effects of organisational context on quality management: An empirical investigation," *Manage. Sci.*, vol. 37, no. 9, pp. 1107–1124, 1991.

[24] J. J. Dahlgaard, S. M. Dahlgaard-Park, and J. J. and D.-P. Dahlgaard S. M., "The 4P quality strategy for breakthrough and sustainable development," *Eur. Qual.*, vol. 10, no. 4, pp. 6–20, 2004.

[25] M. S. Yahya, M. Mohammad, B. Omar, E. F. Ramly, and M. S. Yahya Mohammad, M., Omar, B. and Ramly, E.F., "A review on the selection of lean production tools and techniques," *ARPN J. Eng. Appl. Sci.*, vol. 11, no. 12, pp. 7721–7727, 2016.

[26] A. N. M. Rose M.Deros, B. and A.Rahmah, M.N., "A Study on Lean Manufacturing Implementation In Malaysian Automotive Component Industry," *Int. J. Automot. Mech. Eng.*, vol. 8, pp. 1467–1476, 2013.

[27] N. Nordin Deros, B. M. and Wahab, D. A., N. Nordin, B. Md Deros, and D. Abd Wahab, "A Survey on Lean Manufacturing Implementation In Malaysian Automotive Industry," *Int. J. Innov. Manag. Technol.*, vol. 1, p. 374, 2010.

[28] R. Muslimen Sha'ri Mohd Yusof and Ana Sakura Zainal Abidin, "Lean Manufacturing Implementation in Malaysian Automotive Components Manufacturer: a Case Study," in *World Congress on Engineering*, 2011.

[29] Y. C. Wong Wong, K.Y.,Ali, A., Y. C. Wong, K. Y. Wong, and A. Ali, "A Study on Lean Manufacturing Implementation In the Malaysia Electrical and

Electronics Industry," *Eur. J. Sci. Res.*, vol. 38, p. 521, 2009.

[30] N. S. Khusaini Jaffar, A. and Yusoff, N., N. S. Khusaini, N. Yusoff, and A. Jaffar, "A Survey on Lean Manufacturing Tools Implementation in Malaysian Food and Beverages Industry using Rasch Model," *Adv. Mater. Res.*, vol. 845, pp. 642–646, 2014.

[31] N. Thawesaengskulthai and D. Thawesaengskulthai, "Trends in Quality Management and Industrial Engineering Techniques," *Industrial Engineering Network Conference*. pp. 1000–1005, 2007.

[32] I. Hendra, "Horses for courses - picking your winner when it comes to quality improvement systems," in *QNewZ*, vol. January-Fe, L. Nikoloff, Ed. Palmerston North: New Zealand Organisation for Quality , 2010, pp. 11–14.

[33] R. Basu, *Implementing quality: A practical guide to tools and techniques*. London: Thomson, 2004.

[34] N. Thawesaengskulthai and J. D. T. Tannock, "A decision aid for selecting improvement methodologies," *Int. J. Prod. Res.*, vol. 46, no. 23, pp. 6721–6737, 2008.

[35] T. Ohno, "The Toyota Production System, English translation," *English translation: Productivity Press*, Productivity Press, 1988.

[36] R. Shah and Ward, P. T., "Defining and Developing Measures of Lean Production," *J. Oper. Manag.* , vol. 25, p. 785, 2007.

[37] J. P. Womack, D. T. Jones, and D. Roos, *The Machine that Changed the World.* NewYork: Rawson Associates, 1990.

[38] K. Birdi *et al.*, "The Impact of Human Resource and Operational Management Practices on Company Productivity: A Longitudinal Study," *Pers. Psychol.*, vol. 61, no. 3, pp. 467–501, 2008.

[39] T. Melton, "The benefits of lean manufacturing. What lean thinking has to offer the process industries," *Chem. Eng. Res. Des.*, vol. 83, no. A6, p. 662673, 2005.

[40] J. P. Womack and D. T. Jones, *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*. London: Simon & Schuster, 1996.

[41] B. Zhou and Q. Zhao, "Application of Lean Focus on Manufacturing Process : A Case Study of an American Furniture Company," Jönköping University, 2010.

[42] A. V Hill, "The Encyclopedia of Operations Management: A Field Manual and Glossary of Operations Management Terms and Concepts." FT Press, 2011.

[43] L. J. Krajwski, L. P. Ritzman, and M. K. Malhotra, *Operations Management Process and Supply Chain* , 10th ed. Pearson Education Limited, England., 2013.

[44] S. M. Aghazadeh, "Does Manufacturing Need to Make JIT Delivery Work? ," *Management Research News*, vol. 27, no. 1, 2004.

[45] L. S. Pheng, F. M. Arain, and J. W. Y. Fang, "Applying Just-In-Time Principles in the Delivery and Management of Airport Terminal Buildings," *Built Environ. Proj. Asset Manag.*, vol. 9, no. 1, pp. 104–121, 2011.

[46] W. J. Stevenson, *Operations Management*, 11th ed. Mc. Graw Hill , 2012.

[47] P. Arunagiri and A. Gnanavelbabu, "Identification of High Impact Lean Production Tools in Automobile Industries using Weighted Average Method," *Procedia Eng.*, vol. 97, pp. 2072–2080, 2014, doi: http://dx.doi.org/10.1016/j.proeng.2014.12.450.

[48] D. T. Matt and E. Rauch, "Implementation of Lean Production in Small Sized Enterprises," *Procedia CIRP*, vol. 12, no. 0, pp. 420–425, 2013, doi: http://dx.doi.org/10.1016/j.procir.2013.09.072.

[49] C. D. Chapman, "Clean house with lean 5S," *Quality Progress*, vol. 38, pp. 27–32, 2005.

[50] M. I. Raja, "Lean Manufacturing-an Integrated Socio-Technical Systems Approach to Work Design," Clemson University, 2011.

[51] K. Suzaki, " Japanese manufacturing techniques: their importance to US manufacturers," *J. Bus. Strategy*, vol. 5, no. 3, pp. 10–19, 1985.

[52] S. S. Heragu, "Group technology and cellular manufacturing," *Syst. Man Cybern. IEEE Trans.*, vol. 24, no. 2, pp. 203–215, 1994.

[53] R. Sundar *et al.*, “A Review on Lean Manufacturing Implementation Techniques,” *Procedia Eng.*, vol. 97, pp. 1875–1885, 2014, doi: http://dx.doi.org/10.1016/j.proeng.2014.12.341.

[54] A. Berger, “Continuous improvement and kaizen: standardization and organizational designs,” *Integr. Manuf. Syst.*, vol. 89, no. 2, pp. 110–117, 1997.

[55] D. F. John Bessant, “Developing strategic continuous improvement capability,” *Int. J. Oper. Prod. Manag.*, vol. 9, no. 11, pp. 1106 – 1119, 1999.

[56] R. A. Mike Kaye, “Continuous improvement: the ten essential criteria,” *Int. J. Qual. Reliab. Manag.*, vol. 16, no. 5, pp. 485 – 509, 1999.

[57] A. B. Nadia Bhuiyan, N. Bhuiyan, and A. Baghel, “ An overview of continuous improvement: from the past to the present,” *Manag. Decis.*, vol. 43, no. 5, pp. 761 – 770, 2005.

[58] S. N. Seyedia, S. Hakimia, H. B. Ahmadia, P. Rezvana, and M. Izadifara, “A Decision-Making Process for Selecting of Lean Tools Implementation Methods by Means of Analytical Hierarchy Process in Health Center,” *J. Teknol.*, vol. 64, no. 3, pp. 149–152, 2013.

[59] M. W. Feld, *Lean Manufacturing: Tools, Techniques, and how to use them*. Boca Raton, London: The St. Lucie Press, 2000.

[60] D. A. Arnheiter and J. Maleyeff, “The integration of lean management and Six Sigma,” *TQM Mag.*, vol. 17, no. 1, pp. 5–18, 2005.

[61] M. Rother Shook, J, *Learning to See: Value Stream Mapping to Add Value and Eliminate Muda*. The Lean Enterprise Institute, Inc., Brookline, MA., 1999.

[62] V. A. E. M. McDonald T Rentes A.F, “Utilizing simulation to enhance value stream mapping: a manufacturing, case application,” *Int. J. Logist. Res. Appl.*, vol. 5, no. 2, pp. 213–232, 2002.

[63] J. R. Fawaz A. Abdulmalek, F. A. and R. Abdulmalek J., and J. R. Fawaz A. Abdulmalek, “Analyzing the benefits of lean manufacturing and value stream mapping via simulation: a process sector case study,” *Int. J. Prod. Econ.*, vol. 107, no. 1, pp. 223–236, 2007.

[64] L. Rivera and F. Frank Chen, "Measuring the impact of Lean tools on the cost–time investment of a product using cost–time profiles," *Robot. Comput. Integr. Manuf.*, vol. 23, no. 6, pp. 684–689, 2007, doi: https://doi.org/10.1016/j.rcim.2007.02.013.

[65] H. G. Martinez and W. X. Lu, "Lean thinking literature review and suggestions for future research," *Int. J. Bus. Manag.*, vol. 1, no. 4, pp. 110–118, 2013.

[66] D. P. Hobbs, *Lean manufacturing implementation: a complete execution manual for any size manufacturer*. J. Ross Publishing, 2004.

[67] J. M. Gross & McInnis, K. R., *Kanban made simple: demystifying and applying Toyota's legendary manufacturing process* , vol. 1. Amacom Books, 2003.

[68] M. Sokovic, D. Pavletic, and K. K. Pipan, "Quality Improvement Methodologies -PDCA Cycle, RADAR Matrix, DMAIC and DFSS," *J. Achiev. Mater. Manuf. Eng.*, vol. 43, no. 1, pp. 476–483, 2010.

[69] P. Dennis & Shook, J., "Lean production simplified: a plain language guide to the world's most powerful production system." Productivity Pr., 2007.

[70] I. S. Ahuja, "Total productive maintenance practices in manufacturing organizations: literature review," *Int. J. Technol. Policy Manag.*, vol. 11, no. 2, pp. 117–138, 2011.

[71] R. Smith & Hawkins, B., *Lean maintenance: reduce costs, improve quality, and increase market share*. Butterworth-Heinemann, 2004.

[72] R. K. Singh Kumar, S., Choudhary, A.K. , and Tiwari, M.K., "International Journal of production Research," *Lean tool Sel. a die Cast. unit a fuzzy based Decis. Support heuristic*, vol. 44, no. 7, pp. 1399–1429, 2006.

[73] N. Thawesaengskulthai and D. Thawesaengskulthai, "Doctoral dissertation seminar," Chulalongkorn University, 2007.

[74] D. Miller and J. Hartwick, "Spotting management fads," *Harv. Bus. Rev.*, vol. 80, no. 10, pp. 26–27, 2002.

[75] X. Wang, "A comprehensive decision making model for the evaluation of

green operations initiatives," *Technol. Forecast. Soc. Change*, vol. 95, pp. 191–207, 2015, doi: https://doi.org/10.1016/j.techfore.2015.02.004.

[76] S. Mi, Y. Feng, H. Zheng, Y. Wang, Y. Gao, and J. Tan, "Prediction maintenance integrated decision-making approach supported by digital twin-driven cooperative awareness and interconnection framework," *J. Manuf. Syst.*, 2020, doi: https://doi.org/10.1016/j.jmsy.2020.08.001.

[77] M. H. Bazerman and D. A. Moore, *Judgment in managerial decision making*, 7th ed. New Jersey: John Wiley & Sons Inc., 2009.

[78] N. Thawesaengskulthai, "An empirical framework for selecting quality management and improvement initiatives," *Int. J. Qual. Reliab. Manag.*, vol. 27, no. 2, pp. 156–172, 2010, doi: 10.1108/02656711011014285.

[79] K. P. Yoon & Hwang, C. L., *Multiple attribute decision making: An introduction*. California: Sage Publication Inc., 1995.

[80] Mark Velasquez and P. T. Hester, "An Analysis of Multi-Criteria Decision Making Methods," *Int. J. Oper. Res.*, vol. 10, no. 2, pp. 56–66, 2013.

[81] S. M. B. Sadati, A. Rastgou, M. Shafie-khah, S. Bahramara, and S. Hosseini-hemati, "Energy management modeling for a community-based electric vehicle parking lots in a power distribution grid," *J. Energy Storage*, vol. 38, p. 102531, 2021, doi: https://doi.org/10.1016/j.est.2021.102531.

[82] A. Mostafaeipour, A. Sedaghat, M. Hedayatpour, and M. Jahangiri, "Location planning for production of bioethanol fuel from agricultural residues in the south of Caspian Sea," *Environ. Dev.*, vol. 33, p. 100500, 2020, doi: https://doi.org/10.1016/j.envdev.2020.100500.

[83] Z. Song, H. Gao, W. Liu, L. Li, W. Zhang, and D. Wang, "Systematic assessment of dredged sludge dewaterability improvement with different organic polymers based on analytic hierarchy process," *J. Environ. Sci.*, vol. 103, pp. 311–321, 2021, doi: https://doi.org/10.1016/j.jes.2020.11.017.

[84] T. Aykut, "Determination of groundwater potential zones using Geographical Information Systems (GIS) and Analytic Hierarchy Process (AHP) between Edirne-Kalkansogut (northwestern Turkey)," *Groundw. Sustain. Dev.*, vol. 12, p. 100545, 2021, doi: https://doi.org/10.1016/j.gsd.2021.100545.

[85] S. Kwatra, A. Kumar, S. Sharma, and P. Sharma, "Stakeholder participation in prioritizing sustainability issues at regional level using Analytic Hierarchy Process (AHP) technique: A case study of Goa, India," *Environ. Sustain. Indic.*, p. 100116, 2021, doi: https://doi.org/10.1016/j.indic.2021.100116.

[86] V. L. Sivakumar, R. Radha Krishnappa, and M. Nallanathel, "Drought vulnerability assessment and mapping using Multi-Criteria decision making (MCDM) and application of Analytic Hierarchy process (AHP) for Namakkal District, Tamilnadu, India," *Mater. Today Proc.*, vol. 43, pp. 1592–1599, 2021, doi: https://doi.org/10.1016/j.matpr.2020.09.657.

[87] K. Banerjee, M. B. Santhosh Kumar, and L. N. Tilak, "Delineation of potential groundwater zones using Analytical hierarchy process (AHP) for Gautham Buddh Nagar District, Uttar Pradesh, India," *Mater. Today Proc.*, 2021, doi: https://doi.org/10.1016/j.matpr.2020.12.917.

[88] J. Malczewski, *GIS and Multicriteria Decision Analysis*. John Wiley & Sons, 1999.

[89] T. L. Saaty, *The analytic hierarchy process – planning, priority setting, resource allocation*. New York: McGraw-Hill, 1980.

[90] T. L. Saaty, "How to make a decision - The analytic hierarchy process," *Eur. J. Oper. Res.*, no. 48, pp. 9–26, 1990.

[91] T. L. Saaty, *The Analytical Hierarchy Process*. New York, NY: McGraw-Hill, 1980.

[92] T. J. Crowe Noble, S. J. and Machimada, S. J., "Multi-attribute analysis of ISO9001 registration using AHP," *Int. J. Qual. Reliab. Manag.*, vol. 15, no. 2, pp. 205–222, 1998.

[93] S. K. Fikri Dweiri Sharfuddin Ahmed Khan, and Vipul Jain, "Designing an integrated AHP based decision support system for supplier selection in automotive industry," *Expert Syst. Appl.*, vol. 62, pp. 273–283, 2016.

[94] I. Miciuła and J. Nowakowska-Grunt, "Using the AHP method to select an energy supplier for household in Poland," *Procedia Comput. Sci.*, vol. 159, pp. 2324–2334, 2019, doi: https://doi.org/10.1016/j.procs.2019.09.407.

[95] A. Azimifard, S. H. Moosavirad, and S. Ariafar, "Selecting sustainable

supplier countries for Iran's steel industry at three levels by using AHP and TOPSIS methods," *Resour. Policy*, vol. 57, pp. 30–44, 2018, doi: https://doi.org/10.1016/j.resourpol.2018.01.002.

[96] Y.-K. Fu, "An integrated approach to catering supplier selection using AHP-ARAS-MCGP methodology," *J. Air Transp. Manag.*, vol. 75, pp. 164–169, 2019, doi: https://doi.org/10.1016/j.jairtraman.2019.01.011.

[97] G. Nirmala and G. Uthra, "AHP based on Triangular Intuitionistic Fuzzy Number and its Application to Supplier Selection Problem," *Mater. Today Proc.*, vol. 16, pp. 987–993, 2019, doi: https://doi.org/10.1016/j.matpr.2019.05.186.

[98] E. C. Özcan, S. Ünlüsoy, and T. Eren, "A combined goal programming – AHP approach supported with TOPSIS for maintenance strategy selection in hydroelectric power plants," *Renew. Sustain. Energy Rev.*, vol. 78, pp. 1410–1423, 2017, doi: https://doi.org/10.1016/j.rser.2017.04.039.

[99] D. Meira, I. Lopes, and C. Pires, "Selection of computerized maintenance management systems to meet organizations' needs using AHP," *Procedia Manuf.*, vol. 51, pp. 1573–1580, 2020, doi: https://doi.org/10.1016/j.promfg.2020.10.219.

[100] E. Lima, E. Gorski, E. F. R. Loures, E. A. P. Santos, and F. Deschamps, "Applying machine learning to AHP multicriteria decision making method to assets prioritization in the context of industrial maintenance 4.0," *IFAC-PapersOnLine*, vol. 52, no. 13, pp. 2152–2157, 2019, doi: https://doi.org/10.1016/j.ifacol.2019.11.524.

[101] A. Azadeh, R. Yazdanparast, S. A. Zadeh, and A. E. Zadeh, "Performance optimization of integrated resilience engineering and lean production principles," *Expert Syst. Appl.*, vol. 84, pp. 155–170, 2017, doi: https://doi.org/10.1016/j.eswa.2017.05.012.

[102] A. Azadeh, S. M. Asadzadeh, and M. Tanhaeean, "A consensus-based AHP for improved assessment of resilience engineering in maintenance organizations," *J. Loss Prev. Process Ind.*, vol. 47, pp. 151–160, 2017, doi: https://doi.org/10.1016/j.jlp.2017.02.028.

[103] L. Sagbansua and F. Balo, “Evaluatıon of the Solar Panels in Terms of Energy Effıcıency,” *Int. J. Comput. Trends Technol.*, vol. 42, no. 1, pp. 59–65, 2016.

[104] A. Riahi and M. Moharrampour, “Evaluation of Strategic Management in Business with AHP Case Study: PARS House Appliance,” *Procedia Econ. Financ.*, vol. 36, pp. 10–21, 2016, doi: http://dx.doi.org/10.1016/S2212-5671(16)30011-9.

[105] M. Ikram, R. Sroufe, and Q. Zhang, “Prioritizing and overcoming barriers to integrated management system (IMS) implementation using AHP and G-TOPSIS,” *J. Clean. Prod.*, vol. 254, p. 120121, 2020, doi: https://doi.org/10.1016/j.jclepro.2020.120121.

[106] N. Somsuk and T. Laosirihongthong, “A fuzzy AHP to prioritize enabling factors for strategic management of university business incubators: Resource-based view,” *Technol. Forecast. Soc. Change*, vol. 85, pp. 198–210, 2014, doi: https://doi.org/10.1016/j.techfore.2013.08.007.

[107] W. G. Sullivan and J. R. Canada, *Multiattribute Evaluation of AMS*. New Jersey: Prentice Hall Inc., 1989.

[108] S. K. Patil and R. Kant, “A fuzzy AHP-TOPSIS framework for ranking the solutions of Knowledge Management adoption in Supply Chain to overcome its barriers,” *Expert Syst. Appl.*, vol. 41, pp. 679–693, 2014.

[109] L. A. H. I., W. C. Chen, and C. J. Chang, “A fuzzy AHP and BSC approach for evaluating performance of IT department in manufacturing industry in Taiwan,” *Expert Syst. `with Appl.*, vol. 34, pp. 96–107, 2008.

[110] M. H. Vahidnia, A. Alesheikh, A. Alimohammadi, and A. Bassiri, “Fuzzy analytical hierarchy process in GIS application,” vol. 37, Jan. 2008.

[111] F. F. Nobre, L. T. F. Trotta, and L. F. A. . Gomes, “Multicriteria decision making: An approach to setting priorities in health care,” in *Symposium on statistical bases for public health decision making: from exploration to modeling*, 1999, vol. 18, no. 23, pp. 3345 – 3354.

[112] F. E. Kast and J. E. Rosenzweig, *Organization and management: A systems and contingency approach*, 4th ed. New York, NY: McGraw-Hill, 1985.

[113] L. Donaldson, *The contingency theory of organizations*. California, CA: Sage

Publications, 2001.

[114] R. and V. Sousa C. A., “Contingency research in operations management practices,” *J. Oper. Manag.*, vol. 26, pp. 697–713, 2008.

[115] A. M. Saunders and R. Mann, “Business excellence tools: The tools used by companies at different stages of business excellence maturity,” Centre for Organisational Excellence Research, Palmerston North, 2007.

[116] B. G. Dale, “Tools and techniques: An overview,” in *Managing quality*, 5th ed., B. G. Dale, T. Van der Wiele, and J. Van Iwaarden, Eds. Malden, MA: Blackwell Publishing, 2007, pp. 336–381.

[117] C. Capon, *Understanding organisational context: Inside and outside organisations*, 2nd ed. Harlow: Prentice Hall Financial Times, 2004.

[118] R. Mann, “Business excellence tools: The tools used by companies at different stages of business excellence maturity,” Centre for Organisational Excellence Research, Palmerston North, 2007.

[119] B. G. Dale, *Tools and techniques: An overview. In B. G. Dale, T. Van der Wiele and J. Van Iwaarden (Eds.), Managing quality* , 5th ed. Malden, MA: Blackwell Publishing, 2007.

[120] J. J. and D.-P. Dahlgaard S. M., “The 4P quality strategy for breakthrough and sustainable development,” *Eur. Qual.*, vol. 10, no. 4, pp. 6–20, 2004.

[121] National Institute of Standards and Technology (NIST), “Criteria for Performance Excellence 2008,” 2008. [Online]. Available: http://www.quality.nist.gov/PDF_files/2008_Business_Nonprofit_Criteria.pdf.

[122] NIST, “2011-2012 Education Criteria for Performance Excellence.” [Online]. Available: http://www.nist.gov/baldrige/publications/upload/2011_2012_Education_Criteria.pdf.

[123] M. and M. Saunders R., “Business excellence tools: The tools used by companies at different stages of business excellence maturity,” Centre for Organisational Excellence Research, Palmerston North, 2007.

[124] R. Sousa and C. A. Voss, “Contingency research in operations management

practices," *J. Oper. Manag.*, vol. 26, pp. 697–713, 2008.

[125] M. Mohammad, R. Mann, N. Grigg, and J. . Wagner, "The right improvement initiative for the right situation: A contextual and systems approach," in *Proceedings of the 40th International Conference on Computers and Industrial Engineering*, 2010, pp. 1–6.

[126] J. J. Dahlgaard and S. M. Dahlgaard-Park, "The 4P quality strategy for breakthrough and sustainable development," *Eur. Qual.*, vol. 10, no. 4, pp. 6–20, 2004.

[127] National Institute of Standards and Technology (NIST), "2011-2012 Criteria for performance excellence," 2010. [Online]. Available: http://www.nist.gov/baldrige/publications/upload/2011_2012_Business_Nonprofit_Criteria.pdf.

[128] N. I. of S. and T. (NIST), "2011-2012 Criteria for performance excellence," 2010. [Online]. Available: http://www.nist.gov/baldrige/publications/upload/2011_2012_Business_Nonprofit_Criteria.pdf.

[129] M. Mohammad, R. Mann, N. Grigg, and J. P. Wagner, "Selecting appropriate organisational improvement initiatives: A five steps approach," in *Proceedings of the 15th International Conference on ISO and TQM*, 2011, pp. 1–6.

[130] N. Thawesaengskulthai and J. D. T. Tannock, "Pay-off selection criteria for quality and improvement initiatives," *Int. J. Qual. Reliab. Manag.*, vol. 25, no. 4, pp. 366–382, 2008.

[131] T. Bendell, "Structuring business process improvement methodologies," *Total Qual. Manag. Bus. Excell.*, vol. 16, no. 8–9, pp. 969–978, 2005, doi: 10.1080/14783360500163110.

[132] B. P. Wieleman, "Selecting business improvement methods: Towards a technique for consultants to support the selection of methods in an improvement project," Eindhoven University of Technology, Eindhoven, Netherlands, 2011.

[133] Md Al Amin, "A Systematic approach for Selecting Lean Strategies and

Assessing Leanness in Manufacturing Organizations," Queensland University of Technology, 2013.

[134] N. Radziwill *et al.*, "Starting from scratch - Roadmap and toolkit: recipe for a new quality system," *Qual. Prog.*, vol. 41, no. 9, pp. 40–47, 2008.

[135] P. Pangsri, "A Decision Framework to Select Alternative based on Lean manufacturing Concepts in Design Processes," *J. Ind. Intell. Inf.* , vol. 2, no. 1, pp. 1–5, 2014.

[136] M. A. Mohd Daril, "Intelligent Decision Support System For Selection Of Quality Tools and Techniques Via Categorization Input Function Output Definition Model," Universiti Kuala Lumpur, 2019.

[137] R. Mann, "Revisiting a TQM research project: The quality improvement activities of TQM," *Total Qual. Manag. Bus. Excell.*, vol. 19, no. 7, pp. 751–761, 2008, doi: 10.1080/14783360802159410.

[138] M. S. Litwin, *How to assess and interpret survey psychometrics*, 2nd ed. California: Sage Publications, 2003.

[139] M. Saunders, P. Lewis, and A. Thornhill, *Research methods for business students*, 5th ed. Harlow: FT Prentice Hall, 2009.

[140] D. J. Delgado-Hernandez and Elaine M. Aspinwall, "Improvement Tools in the UK Construction Industry," *J. Constr. Manag. Econ.*, vol. 23, no. 9, pp. 965–977, 2005.

[141] T. Panneman, "Lean Transformations - when and how to climb the four steps of Lean maturity," *Maarssen (NL)*, 2017. .

[142] F. Jorgensen, R. Mathiessen, J. Nielsen, and J. Johansen, "Lean Maturity, Lean Sustainability," *Adv. Prod. Manag. Syst.*, vol. 246, pp. 371–378, 2007.

[143] U. Sekaran, *Research Methods for Business: A skill building approach*. Singapore: John Wiley & Sons Inc., 2005.

[144] R. Mann and R. Smith, "Constructs and systems: Connecting strategy deployment and performance excellence," *Total Qual. Manag. Bus. Excell.*, vol. 20, no. 1, pp. 115–128, 2009, doi: 10.1080/14783360802614323.

[145] A. Tashakkori and C. Teddlie, *Mixed methodology: combining the qualitative*

and quantitative approaches. California: Sage publications, 1998.

[146] Y. S. Lincoln and E. G. Guba, *Naturalistic inquiry*. Newbury Park, CA: Sage Publications, 1985.

[147] A. B. Dellinger and N. L. Leech, “Toward a unified validation framework in mixed methods research,” *J. Mix. Methods Res.*, vol. 1, no. 4, pp. 309–332, 2007, doi: 10.1177/1558689807306147.

[148] A. O’Cathain, “Assessing the quality of mixed methods research,” in *SAGE Handbook of Mixed Methods in Social & Behavioral Research*, 2nd ed., A. Tashakkori and C. Teddlie, Eds. Thousand Oaks, CA: SAGE Publications, 2010, pp. 531–555.

[149] J. W. Creswell and V. L. P. Clark, *Designing and conducting mixed methods research*, 2nd ed. Thousand Oaks, CA: Sage Publications, 2011.

[150] S. French and D. L. Xu, “Comparison study of multi-attribute decision analytic software,” *J. Multi-Criteria Decis. Anal.*, vol. 3, no. 2–3, p. 65, 2005.

[151] P. McGinley, “Decision analysis software survey,” 2012.

[152] F. T. S. Chan and H. K. Chan, “An AHP model for selection of suppliers in the fast changing fashion market,” *Int. J. Adv. Manuf. Technol.*, vol. 51, no. 9–12, p. 1195, 2010.

[153] A. Najafi and A. Afrazeh, “Analysis of the Environmental Projects Risk Management Success Using Analytical Network Process Approach,” *Int. J. Environ. Res.*, vol. 5, no. 2, pp. 277–284, 2011.

[154] B. O. Saracoglu, “Selecting industrial investment locations in master plans of countries,” *Eur. J. Ind. Eng.*, vol. 7, no. 4, pp. 416–441, 2013.

[155] K. Pažek, Č. Rozman, F. Bavec, A. Borec, and M. Bavec, “A Multi-Criteria Decision Analysis Framework Tool for the Selection of Farm Business Models on Organic Mountain Farms,” *J. Sustain. Agric.*, vol. 34, no. 7, p. 778, 2010.

[156] I. Alessio and L. Ashraf, “Analytic Hierarchy Process and Expert Choice: Benefits and Limitations,” *ORInsight*, pp. 201–220, 2009.

[157] Expertchoice.com, “Prepare for real-world decision making with the ideal

practic." [Online]. Available: https://www.expertchoice.com/academic-program/expert-choice-academic-licenses/.

[158] T. L. Saaty, "About SuperDecisions," *RWS Publication*, 1996. [Online]. Available: http://www.superdecisions.com/about/.

[159] M. Henn, M. Weinstein, and N. Foard, *A Short Introduction to Social Research*. London: Sage Publications Ltd., 2006.

[160] U. Sekaran and R. Bougie, *Research methods for business: A skill building approach*. John Wiley & Sons, 2016.

[161] B. M. D. Norani Nordin Dzuraidah Abdul Wahab, Mohd Nizam Ab. Rahman, N. Nordin, D. Abdul Wahab, M. N. Ab. Rahman, B. Md Deros, and B. M. D. Norani Nordin Dzuraidah Abdul Wahab, Mohd Nizam Ab. Rahman, "Validation of Lean Manufacturing Implementation Framework Using Delphi Technique," *J. Teknol. (Sciences Eng.* , vol. 59, no. 2, pp. 1–6, 2012.

[162] M. A. Sahwana, M. N. A. Rahman, and B. M. Deros, "Barriers to Implement Lean Manufacturing in Malaysian Automotive Industry," *J. Teknol. (Sciences Eng.*, vol. 59, no. 2, pp. 107–110, 2012.

[163] M. Vorkapić, D. Ćoćkalo, D. Đorđević, and C. Bešić, "Implementation of 5S tools as a starting point in business process reengineering," *J. Eng. Manag. Compet.*, vol. 7, no. 1, pp. 44–54, 2017.

[164] T. Laosirihongthong, "Revisiting Quality Management and Performance," *Ind. Manag. Data Syst.*, vol. 113, no. 7, pp. 990–1006, 2013.

[165] M. Tickle, D. Adebanjo, Robin Mann, and F. Ojadi, "Business Improvement Tools and Techniques: Comparison Across Sectors and Industries," *Int. J. Prod. Res.*, vol. 53, no. 2, pp. 354–370, 2015.

[166] N. . Burgess and Z. Radnor, "Evaluating Lean in Healthcare," *Int. J. Health Care Qual. Assur.*, vol. 26, no. 3, pp. 220–235, 2013.

[167] Z. Huq and J. D. Stolen, "Total Quality Management Contrasts in Manufacturing and Service Industries," *Int. J. Qual. Reliab. Manag.*, vol. 15, no. 2, pp. 138-161., 1998.

[168] U. Elg and J. Hultman, "Retailers' Management of Corporate Social

Responsibility (CSR) in Their Supplier Relationships – Does Practice Follow Best Practice?," *Int. Rev. Retail. Distrib. Consum. Res.*, vol. 21, no. 5, pp. 445–460, 2011.

[169] N. A. A. Mohammad, M., Yaakub, N. H., Yahya, M. S., & Hamid, M. Mohammad, H. Yaakub, M. S. Yahya, N. Aziati, and A. Hamid, "Awareness, Implementation, Effectiveness and Future Adoption of Operational Improvement Initiatives: Survey Results," in *Proceeding of the 2016 International Conference on Industrial Engineering and Operation Management*, 2016, pp. 1–6.

[170] M. N. A. Rahman, C. K. Ho, M. A. A. Abusin, and J. A. Ghani, "Pembentukan TPS dalam Pembuatan Lean: Satu Kajian Perbandingan," *J. Teknol. (Sciences Eng.*, vol. 63, no. `, pp. 21–33, 2013.

[171] F. Abdullah, "Lean Manufacturing Tools and Techniques in the Process Industry with a Focus on Steel," University of Pittsburgh, 2003.

[172] E. Andrés-López, I. González-Requena, and A. Sanz-Lobera, "Lean Service: Reassessment of Lean Manufacturing for Service Activities," *Procedia Eng.*, vol. 132, pp. 23–30, 2015, doi: https://doi.org/10.1016/j.proeng.2015.12.463.

[173] J. Wang, *Lean manufacturing _ business bottomline based*. LLC: CRC Press, Taylor and Francis Group, 2011.

[174] L. Wilson, *How to Implement Lean Manufacturing*. New York: McGraw-Hill, 2010.

[175] L. Wilson, *How to Implement Lean Manufacturing*. New York: McGraw-Hill, 2010.

[176] S. M. Satao Thampi, G.T., Dalvi, S. D., Srinivas, B., and Patil, T. B., "Enhancing Waste Reduction through Lean Manufacturing Tools and Techniques, a Methodical Step in the Territory of Green Manufacturing," *Int. J. Res. Manag. Technol.*, vol. 2, no. 2, pp. 253–257, 2012.

[177] P. J. Kalkowska and J. Kalkowska, "Implementation Selected Tools of Lean Manufacturing," Poznan University of Technology, Barchelona, 2013.

[178] N. A. A. Rahman Sharif, S. M., & Esa, M. M., N. A. A. Rahman, S. M. Sharif, and M. M. Esa, "Lean Manufacturing Case Study with Kanban System

Implementation," *Procedia Econ. Financ.*, vol. 7, pp. 174–180, 2013, doi: http://dx.doi.org/10.1016/S2212-5671(13)00232-3.

[179] T. L. Saaty, *The analytic hierarchy process*. New York, NY: Pergamon Press, 1988.

[180] T. L. Saaty, *Fundamental of decision making and priority theory with the analytic hierarchy process*. Pittsburgh, PA: RWS Publication, 2000.

[181] F. Talib Rahman, Z. and Qureshi, M.N., "Prioritising the practices of total quality management: An analytical hierarchical process analisis for the service industries," *Total Qual. Manag.*, vol. 22, no. 12, pp. 1331–1351, 2011.

[182] N. F. Schneidewind and H.-. Hoffmann, "An Experiment in Software Error Data Collection and Analysis," *IEEE Trans. Softw. Eng.*, vol. SE-5, no. 3, pp. 276–286, 1979, doi: 10.1109/TSE.1979.234188.