CONCEPTUAL ANALYSIS OF LEAN PRINCIPLES AND TOOLS IN MANUFACTURING INDUSTRIES

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references. Bibliography/references are appended.

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LIST OF ABBREVIATIONS

VSM	Value Stream Mapping
LM	Lean Manufacturing
PDCA	Plan-Do-Check-Act
DMAIC	Define-Measure-Analyze-Improve-Control
VM	Visual Management
WIP	Work In Process
RCA	Root Cause Analysis
TPS	Toyota Production System
ANOVA	Analysis Of Variance
JIT	Just-In-Time

ANALISIS KONSEP PRINSIP DAN ALAT LEAN DALAM INDUSTRI PEMBUATAN

ABSTRAK

Hari ini, idea dan teknik Pengurusan Lean (PL) digunakan secara meluas oleh syarikat -syarikat di seluruh dunia untuk mengurangkan sisa dan membuat proses lebih berkesan. Metodologi Lean diakui secara meluas sebagai salah satu kaedah yang paling berkesan untuk meningkatkan produktiviti organisasi dan, dengan lanjutan, tahap daya saingnya. Tujuan kertas ini adalah untuk mencari status pelaksanaan prinsip dan alat Lean di seluruh organisasi pembuatan Malaysia melalui metodologi tinjauan empirikal. Makalah ini memberikan perbincangan mengenai idea dan teknik tanpa lemak yang telah dilaksanakan di industri Malaysia yang terlibat dalam pembuatan. Soal selidik tinjauan telah dibangunkan berdasarkan kajian literatur yang dijalankan di PL dan juga dianggap sebagai cadangan pakar dalam bidang PL. Soal selidik tinjauan dihantar kepada 120 responden yang kini bekerja di industri perkilangan yang terletak di Malaysia. Responden terpilih adalah pengurus pengeluaran, pengurus kualiti, pengurus jualan, pengurus penyelenggaraan, dan juga pelajar kejuruteraan. Kajian empirikal mengumpul 107 soal selidik tinjauan yang dipenuhi dari industri perkilangan Malaysia. Kajian ini memberikan sumbangan dengan menonjolkan hubungan memohon alat kurus kepada prinsip -prinsip ramping dalam konteks sektor perkilangan Malaysia. Dalam prinsip pembuatan Lean, lima peraturan utama digunakan untuk mengukur leanness. Prinsip -prinsip ini termasuk nilai, aliran nilai, aliran, tarikan, dan kesempurnaan. Di samping itu, analisis menggambarkan bagaimana lima prinsip Lean yang berbeza menyambung kepada alat Lean yang terdapat dalam sistem pengeluaran. Walau bagaimanapun, bagi organisasi untuk berjaya melaksanakan Lean, ia mesti memilih alat terbaik untuk pengeluaran. Terdapat banyak alat Lean, seperti pemetaan aliran nilai, pembuatan selular, sistem U-line, pengimbangan garis, kawalan inventori, pertukaran satu minit dies, sistem tarik, dan Kanban. Oleh itu, agak sukar untuk memilih alat yang tepat untuk dilaksanakan di syarikat mereka dan mencapai matlamat setiap prinsip. Dalam makalah ini, usaha telah dibuat untuk menentukan alat mana yang boleh digunakan untuk setiap prinsip Lean dengan mengumpul tinjauan dan melihat kepentingan persiapan syarikat untuk melaksanakan sistem pembuatan Lean.

CONCEPTUAL ANALYSIS OF LEAN PRINCIPLES AND TOOLS IN MANUFACTURING INDUSTRIES

ABSTRACT

Today, the ideas and techniques of Lean Manufacturing (LM) are utilised extensively by companies all over the world to reduce waste and make processes more effective. The Lean methodology is widely acknowledged as one of the most effective methods for boosting an organization's productivity and, by extension, its level of competitiveness. The purpose of this paper is to find the implementation status of Lean principles and tools across Malaysian manufacturing organizations through the empirical survey methodology. This paper provides a discussion of lean ideas and techniques that have been implemented in the Malaysian industries involved in manufacturing. The survey questionnaire was developed based upon literature review conducted on LM and also considered experts suggestion in the field of LM. The survey questionnaire was sent to 120 respondents that are currently working in manufacturing industries located in Malaysia. The selected respondents were production managers, quality managers, sales managers, maintenance managers, and also engineering students. The empirical survey collected 107 filled survey questionnaires from Malaysian manufacturing industries. This study makes a contribution by highlighting the relationship of applying lean tools to lean principles within the context of the Malaysian manufacturing sector. study. In lean manufacturing principles, five primary rules are used to measure leanness. These principles include value, value stream, flow, pull, and perfection. In addition, the analysis illustrates how the five different lean principles connect to the lean tools present in the production system. However, for an organization to successfully implement lean, it must choose the best tools for production. There are many lean tools, such as Value Stream Mapping (VSM), Cellular Manufacturing (CM), U-line System, Line Balancing, Inventory Control, Single Minute Exchange of Dies (SMED), Pull System, and Kanban. Thus, it is quite hard to select the right tool to implement in their company and achieve each principle's goals. In this paper, an effort has been made to determine which tools can be used for each lean principle by collecting a survey and seeing the significance of the company's preparation for implementing the lean manufacturing system.

CHAPTER ONE: INTRODUCTION

1.1 Research Background

The manufacturing industry now operates in a challenging and competitive environment due to globalization. A significant influence on the profitability of a Malaysian manufacturing company comes not only from the danger posed by the East but also from the volatility of the rand in comparison to the world's most important currencies. The ongoing economic crisis has affected every organization in every country (Hines, Found, Griffiths & Hamson, 2008). Many organizations were forced to engage in widespread layoffs to keep up with the situation and prepare for the crisis. As a direct consequence of the reduction in staff, employees have been overworked and inundated with additional responsibilities, which has led to feelings of being overworked and quality fatigue (Gagnon, Jansen & Michael, 2008:430). The global tank market is anticipated to expand at a rate of ten percent each year over the next five years. Three major factors will have a significant impact on the future of the tank container industry in Malaysia and around the world: the increasing cost of stainless steel, the growing dominance of Chinese manufacturers, and the weakening of the Malaysian ringgit. Compared to the weak dollar, the strong rand has many benefits for Malaysia but is not beneficial for the tank industry. This is because the tank industry does significant business with dollar-based companies. Due to the euro's strength, most of the tank industry's customers are European companies.

The implementation of ring-fencing, the subsequent elimination of tax shelters, and the subsequent partial relaxation of exchange controls all served to reduce the attractiveness of the tank container investment scheme for Malaysian investors; and the strength of the rand against the dollar since 2002, in the face of increasing competition from Chinese manufacturers. In addition, the introduction of ring-fencing served to reduce the attractiveness of the tank container investment scheme for Malaysian investors; and the strength of the rand against the dollar in the face of increasing competition from the organizational culture and the environment in which these organizations work is to blame for the fact that Malaysian organizations, in contrast to Japanese organizations, are still falling behind in implementing lean thinking. The use of mass production, job specialization, and a hierarchical structure are distinguishing characteristics of Malaysian organizations. Consequently, organizations in Malaysia continue to lag behind those in Japan and China, where Lean has developed into a culture and provides a competitive advantage when competing with world-class manufacturing. In Malaysia, Lean has not yet reached this level of maturity. China and Japan's manufacturing systems have increased their productivity while simultaneously lowering costs thanks to implementing Lean principles and tools. Consequently, Lean can acquire an advantage over its competitors. Therefore, the purpose of this research is for the researcher to determine the most effective lean tools that can be utilized to achieve the objectives of each principle by proving and demonstrating the evidence through an analysis concept.

1.2 Problem Statement

Research on lean ideas and techniques in the industrial industry is now undergoing conceptual study. When you think about it, this is happening in the manufacturing sector. Lean concepts and practices in organisations, especially industrial ones, have received little documented study. In the United States, this is particularly true. This is especially true for companies that are engaged in manufacturing. Despite this, insufficient data supports the assertion that lean principles and lean tools are linked. 'Lean' is a term used to describe lean concepts and methods. This is because lean tools have not been around long enough to gather enough information. There is a lack of focus on the appropriate lean tools that may be used to achieve the goals of each lean principle. In general, reading about lean is a frustrating experience. As a result, even though these devices are readily available, this is the present situation. One of the most annoying parts of the Lean methodology is that it is a requirement of the technique. Because of this, the study's primary purpose will be to investigate the nature of the link between lean production's guiding principles and the practices used to achieve those objectives.

1.3 Research Objectives

This study has two specific objectives as follows:

1. To determine the most effective lean tools that can be applied to achieve each lean principle's goals.
2. To analyse the relationship between lean principles and tools through a research survey and analysis.

1.4 Scope of Research

This research attempted to provide a recommendation for a remedy, which would be to perform a Survey Research with organizations or businesses that are engaged in manufacturing and have previously used the idea of lean. The respondents who will be the focus of this investigation will be given a comprehensive questionnaire about the research.

1.5 Thesis Outlines

This thesis is divided up into six different segments. It begins with the first chapter, which serves as an introduction and contains background information for this research. The second chapter presents a study of the relevant literature to determine and support the factors connected to this research. The methodology, research techniques, and analytical framework that depict the creation of survey instruments and data collecting are presented in chapter three. The findings of the analysis and interpretation are presented and discussed in chapter four. This chapter contains tables with the data gathered to illustrate the study's general findings. After that, the analysis discussion will take place in chapter five, presenting the interpretation based on the acquired findings. The conclusion of the thesis is found in chapter six, which provides a summary from the discussion section. The research results are reviewed in this chapter, including its theoretical and managerial implications, the study's limitations, suggestions for further research, and a conclusion.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter provides a literature study on Lean concepts and techniques to construct the proper knowledge base. It starts with a brief introduction and description of Lean and its primary goals. The chapter explains the lean principles, followed by a treatment of each concept individually. Afterwards, proceed with the Lean tools by providing definitions, goals, and approaches for each. After that, the attention will shift to moving into current literature discussing the link between lean concepts and lean tools. This will take place after the previous step has been completed and a brief review of the results of the previous research.

2.2 Lean Manufacturing

The Lean approach is a rigorous technique for limiting or doing away with jobs that do not offer value to the process. It focuses an emphasis on getting rid of redundant steps in a cycle and doing only the activities that generate value. The Lean approach provides both outstanding quality and total satisfaction for the customer. It helps cut down on the amount of time required for a process cycle, speeds up the delivery of a product or service, lowers the risk that a defect will be generated, cuts down inventory levels, and optimises resources for making crucial improvements. It is an approach to waste disposal that never comes to an end, which serves to foster a never-ending cycle of growth. Krafcik (1988) is credited with being the first person to propose the phrase "lean" to describe the Toyota Production System (TPS), the purpose of which is to achieve a continuous flow. This is in contrast to the mass production approach that Ford adopted at the time (Womack et al., 1990). (Womack et al., 1990). In contrast to traditional production, which focuses on growing inventory, lean manufacturing takes the idea of inventory waste into mind (Gupta and Jain, 2013). Manufacturers must reduce non-value-added procedures, also known as wastes, in order to attain Lean manufacturing practises (Liker, 2004). (Liker, 2004). This permits the product to move through the operations without being interrupted (Ohno, 1988). (Ohno, 1988). As a consequence, "Lean Manufacturing" is characterised as a system whose major objective is to get rid of waste (Shah and Ward, 2007), with the ultimate goal of manufacturing things at the lowest feasible cost and in the shortest amount of time possible to fulfil the demands of the customer (Bhamu and Sangwan, 2014). (Bhamu and Sangwan, 2014). There were a total of seven wastes that were detected (Ohno, 1988), and a summary of their individual descriptions may be seen in Table 2.1 below.

Table 2.1: Description of seven wastes

Waste	**Description**
Overproduction	Produces additional products that have not been ordered and generate overstaffing, storage and transportation costs due to excess inventory.
Waiting	Workers have no work, merely watching and standing around for the next processing step. This may be due to stockouts, lot delays, equipment downtime and capacity bottleneck.
Unnecessary transport	Inefficient movement of WIP due to long distances.
Overprocessing	Unnecessary steps and inefficient processing due to poor tools or product design.
Excess inventory	Extra raw material, WIP and finished goods cause longer lead time, obsolescence, damaged goods, transportation cost, storage cost and delay. Extra inventories hide problems such as imbalance production, supplier late delivery, defects, equipment downtime and long setup time.
Unnecessary movement	Wasted motion such as walking, looking for, reaching for and stacking parts or tools.
Defects	Defective parts which need repair, rework, scrap and inspection cause wasteful handling, time and effort.

2.3 Lean Principles

A widely referred book, Lean Thinking: Banish Waste and Create Wealth in Your Corporation, which was released in 1996, set forth five lean principles, which many in the industry regard as basic concepts. These Lean principles apply to every group, company, and field and may be used interchangeably. Understanding how to properly implement lean concepts inside your organization is essential to practising lean management successfully. The most important thing to remember is that lean management concepts concentrate teams on generating continual progress. When Lean is properly implemented, teams and the processes they employ to give Value to customers get stronger over time. This is true for the teams and the consumers they serve. Continuous improvement often entails analyzing already-established company procedures to streamline and speed up the route to delivering Value to current consumers. Adopting a lean mindset often results in introducing a number of process enhancements that, when added together, result in significant gains in terms of both productivity and product quality. Iterative advancement is informed by the feedback received from clients. The team members talk to one another about their insights through the knowledge work, further strengthening the processes.

The concepts of Lean Management, when correctly applied, provide a self-reinforcing feedback loop that involves both the members of the team and the consumers. It is for this reason that Lean places equal importance on making efforts to improve processes as it does on the work product itself. Additionally, this is another reason why Lean principle are suitable for constructing efficient feedback loops. In addition to improving processes, one of the goals is to correctly identify the obstacles that stand in the way of progress. One such obstacle is the realization that planning a piece of work several months in advance should be considered waste in the Lean sense – a topic discussed in greater depth in the following paragraphs. However, there is more to it than just locating and eliminating waste. It is important to have a singular focus on eliminating obstacles that slow down the process of giving value to consumers. Take advantage of the situation as a learning opportunity if you discover anything that does not adhere to the Lean principles. Talk about it with the rest of your team. Discuss your victories, but it is necessary to talk about your defeats. This is how you practise continuous improvement in Lean; by sharing what worked well or didn't work at all, you are learning with your team and demonstrating the Lean principle of creating knowledge. Continuous improvement in Lean is accomplished by sharing what worked well or what did not work at all.

2.3.1 Value

The first of the five important Lean principles—a clear and unambiguous declaration of Value—serves as a compass for the company's overall direction inside a Lean organisation. The customer determines the value, but the producer generates it. Customers' views of the value of a company's products and services are crucial information for the company, since it allows them to assess the amount of money customers are ready to spend. To fulfil customer needs while maintaining a high level of profitability, the company must eliminate as much unnecessary waste and expenditure as possible from its corporate processes. All team members, from upper management to front-line employees, may reference a compass when contemplating short- and long-term strategy, day-to-day performance and operations assessment, and specialised initiatives for continuous improvement (projects). Included are frontline employees. Recognizing Value, along with the development of "mission, vision, and values" (MVV) statements, is an essential initial step in any Lean journey. MVV is an abbreviation meaning "mission, vision, and values." Lean is not a process; rather, it is a tool for attaining objectives and generating solutions. The lean notion of value and MVV should be linked, but the lean concept of value should not be just MVV repackaged. The purpose of properly defining Value is to provide a statement that any member of an organisation can implement and extend across the supply chain. This statement will serve as a universal compass for assessing each employee's work as well as the wasted resources, including time.

2.3.2 Value Stream

After determining the Value, which is the ultimate objective of the project, the next stage is to map the value stream. The value stream is comprised of all the steps and procedures that are required to take a particular product from its raw materials to its finished form and then deliver it to the consumer. The purpose of this approach is to locate areas of waste and discover chances for improvement. To do this, the strategy entails assembling and carrying out an analysis of the flow of information or resources that are necessary to produce a certain product or service. Through the process of value stream mapping, the whole lifespan of a product is analysed and mapped out, beginning with the product's basic materials and ending with its disposal. The firms have a duty to conduct waste inspections at each and every step of the manufacturing process. It is essential to get rid of anything that is not contributing anything of worth. Lean thinking might be used as a tool to help with supply chain alignment, which is one of the components of this effort. Because it identifies all of the stages that are required to move a product or service through any firm, the method of value stream mapping is basic while while providing informative information. This process could involve designing, producing, making purchases, dealing with human resources and administration, delivering products to clients, or providing services to them. The goal of this activity is to create a flowchart representing the movement of product and material through the process, and to do it on a single piece of paper. The objective here is to single out each stage of the procedure that does not directly contribute to the production of value and then to devise ways to do away with those steps of the procedure that are superfluous. Both "process re-engineering" and "value-stream mapping" are terms that may be used interchangeably with one another. As a result of taking part in this activity, you will, in the end, have a clearer understanding of how the business as a whole operates.

2.3.3 Flow

The following phase, which comes after the waste has been eliminated from the value stream, is to make certain that the remaining processes go without any disruptions, delays, or bottlenecks. Lean's end objective is to streamline business processes so that they run more smoothly. After all of the waste has been cut down, every process has been enhanced, and the surplus inventory has been removed, you will be left with work that flows through operations with ease. Flow is a topic that is often discussed with reverence. During my time working with senses from a leading Japanese consulting business, flow was a topic that came up rather regularly. The term "flow" was one of the two words that they would utter in English to emphasize its significance. The word "waste" was the other. Having smooth-running operations is an essential component of beautiful production, whether you're working in an office or a factory. However, it might take a significant amount of time to truly attain flow. To become a genuine master at making activities run smoothly requires years of practise. Because of this, there aren't very many businesses that are good at it. Flow refers to the connection of value-adding phases in a process in an effortless manner. The majority of individuals believe they have achieved flow when there is seamless interaction between people and materials. However, this is not all.

As more and more details are uncovered, it becomes clearer how the flow of information contributes to the overall picture. You can observe how the equipment contributes to the flow. Flow development involves even the contributions of engineering. The ups and downs of sales may be evened out by marketing, which has an effect on flow. The shop floor is not the only place where flow may be achieved. Flow is often used interchangeably with a number of different concepts when referring to Lean operations.

Continuous flow, one-piece flow, and single piece flow are essentially interchangeable terms that refer to the same phenomenon. The more descriptive ones, on the other hand, focus on the objective of ensuring that a single element (or work unit, in the case of Lean office operations) may move freely through a system.

2.3.4 Pull

The Pull matches the consumer's demand rate with production but is not over-producing. Most organizations will have to push to a certain point and respond to a final customer from that point. The idea with Lean is to drive this point as far upstream in the product-making process as possible, wait for demand, and then make the product fast and with high quality. So, suppose the delivered products have defects. In that case, only a small batch of products will have been affected (Pieterse et al., 2018:12). Pull principle is a production system where a manufacturing company has an explicit limit on the amount of work in process (WIP) that can be in the system. In essence, there is a limit to the WIP. The pull principle differs from the push principle (explicitly has no limits to the amount of work in process in the system). In the pull principle, retailers and manufacturers work together. In concrete terms, retailers provide manufacturers with information on inventory and sales figures, based on which manufacturers then ensure the supply of goods. Repeat orders are placed based on actual demand, which means that goods are produced at short notice. Efficient logistics, fast information flows and functioning information transfer are indispensable because only when they work together can they guarantee the high flexibility of production. Only a comparatively small warehouse is required to implement the pull principle – this principle optimises the respective company's warehouse size.

2.3.5 Perfection

Accomplishing Principles 1-4 is a great start, but the fifth step is perhaps the most important: making lean thinking and process improvement part of your corporate culture. As gains continue to pile up, it is crucial to remember lean is not a static system and requires constant effort and vigilance to be perfect. Every employee should be involved in implementing lean. Lean experts often say that a process is not genuinely lean until it has been through value-stream mapping at least half a dozen times. Setting extremely high standards within your manufacturing company will keep everyone on their toes, even though achieving perfection is rarely possible. Lean manufacturing is a set of principles that can be easily incorporated into a company's culture to ensure that there is always an effort to improve and expand the business. It is an ongoing process to investigate and identify the factors that lead to problems with production quality and waste in production. However, once the location is found, businesses will be compelled to make genuine changes and delve deeper into possible advancements. This will keep competition healthy and the industry moving forward.

2.4 Lean Tools

Many tools and approaches for lean manufacturing have been created throughout the years, and every day new ones are presented (Schonberger 1982, Dillon et al. 1985, Womack et al. 1990, Barker 1994, Liker et al. 1995, Cusumano and Nobeoka 1998, Liker1998, Feld 2000, Taylor and Brunt 2001). Because there is such a wide variety of tools and strategies, it is necessary and beneficial to arrange them in a methodical and rational way. An organized and systematic presentation of these tools will greatly assist in successfully using these techniques, not to mention lean. For instance, simplifying the process of selecting tools for improvement by categorizing them according to the types of resources they may be applied would be accomplished by creating a list of such tools. Taylor and Brunt (2001) developed a simple correlation matrix that relates seven distinct value stream mapping tools—process activity mapping, supply chain response matrix, production variety funnel, quality filter mapping, demand amplification mapping, decision point analysis, and physical structure volume and Value—to the seven fundamental types of waste that Ohno and Shingo identified. These tools are production variety funnel, quality filter mapping, demand amplification mapping, decision point analysis, and physical structure volume and Value. The correlation matrix is consulted to determine which value stream mapping techniques are most suitable to eliminate a specific waste. Taylor and Brunt also recognized various regularly occurring critical processes in an organization. These operations included seven wastes in the value stream of component and assembly manufacturing, seven in work environments, and waste in warehousing. While it is essential to understand and categorize the tools used in lean manufacturing, it is also necessary to consider the relationship of these tools and techniques to the components of the manufacturing organization, the problems they attempt to solve, the type of waste they address, and the resources to which they are applied. Table 2.2 illustrates the summary of the tool's categorization of each principle. All the tools can be considered experimental to determine the relationship between Lean principles and Lean Tools.

Table 2.2: Essential Lean Manufacturing Principles and Tools

	Lean Principles				
	Value	Value Stream	Flow	Pull	Perfection
Lean Tools	DMAIC	Process map	Mistake proofing/Poka-yoke	Current state map	5S
	Pull system	SMED	Visual Management	Pull system	Brainstorming
	Takt time	5S	Full diagram	Flow diagrams	Continuous flows
	Levelled production	VSM	Future state map		Kanban
	Cellular manufacturing	PDCA			VSM
	Visual control	Quality maintenance			5whys
	Kanban/Pull production				Pareto chart
					Run chart

2.4.1 Kaizen

The term "kaizen" originates in Japanese, but it is now commonly used in many western businesses. The term refers to an approach that involves making incremental changes to the established procedures of a job (Chen et al., 2000). It is a compound word that combines the following two ideas: Kai (change) and to one's benefit (through Zen) (Palmer, 2001). The phrase originates from the Gemba Kaizen philosophy, which translates to "Continuous Improvement" (CI). Continuous improvement is necessary in today's highly competitive environment, as it is one of the central strategies for achieving excellence in production (Dean and Robinson, 1991). It requires continuous efforts for improvement on the part of each and every employee in the organization (Malik and YeZhuang, 2006).

In 1950, Japanese management and government officials recognized that there was a problem with the existing confrontational management system as well as an impending labour shortage. This realization led to the birth of the kaizen concept. Japan endeavoured to find a solution to this issue by working closely with the labour force. The groundwork had been laid in the labour contracts that the government had championed, and it was taken up by most major companies. These companies introduced guidelines for distribution of benefits for the development of the company, as well as lifetime employment. This contract continues to serve as the foundation for all Kaizen activities, supplying the essential assurance required to inspire confidence among the labour force (Brunet, 2000). Imai was the first to implement and use it in 1986 with the goal of enhancing efficiency, productivity, and competitiveness in Toyota, a Japanese automobile manufacturing company. This was done in response to the growing pressures of globalization and increased competition. Since then, Kaizen has been incorporated into the manufacturing system in Japan and has made a significant contribution to the country's overall manufacturing success (Ashmore, 2001).

2.4.1.1 Plan-Do-Check-Act (PDCA)

Plan-Do-Check-Act (PDCA), a four-step iterative approach, is a strategy for resolving problems, enhancing products, services, and processes, and making appropriate improvements. It comprises running a number of prospective solutions through a series of tests, analysing the results, and implementing the solutions that are successful. This technique of problem-solving, which is based on the scientific method, is generally ascribed to Dr. W. Edwards Deming, who is widely recognised as the father of contemporary quality control. A simple approach that is effective and efficient is provided by the Problem-Solving, Analyzing, Designing, Construction, and Evaluation (PDCA) Cycle. It enables businesses to generate hypotheses about the areas of their operations that need improvement, test those hypotheses in a continuous feedback loop, and gain priceless knowledge and experience as a result. It promotes piloting new ideas on a smaller scale before changing organizational-wide work procedures and methods. The four components of the PDCA cycle are as follows:

a. Create a strategy: Identify the problem at hand, gather any relevant data, fully study the circumstances, develop many hypotheses on the issues, and choose one of them to put to the test.
b. Execute - Develop and put into practise a solution; choose a metric to assess how effectively it functions; test a potential solution; and assess the results of the test.
c. Check: Confirm the results by comparing the data collected at the start and conclusion of the procedure. Investigate the outcome, ascertain its effectiveness, and then assess if the hypothesis can be supported.
d. Take action: Record the results, inform others of process adjustments, and provide suggestions for more PDCA cycles. If the suggested solution is judged to be successful, it should be implemented; if not, the PDCA process should be resumed with the next problem.

2.4.1.2 Define, Measure, Analyze, Improve, Control (DMAIC)

In 1987, Mikel Harry and Bill Smith from Motorola were the ones who initially devised the DMAIC methodology as one of the quality initiatives associated with the Six Sigma initiative. These five processes are referred to by the abbreviation "DMACI," which stands for "define, measure, analyse, control, and improve." After a few decades, a significant number of companies have adopted the DMAIC method, which is one of the instruments that make up the Six Sigma toolkit. As a result of their accomplishments, a number of fruitful case studies, and the vast range of applications that they may be put to, it has been shown that these high-quality tools are effective. The DMAIC approach is excellent for tackling a broad variety of challenges that emerge in the manufacturing industry. This is because it focuses on more than simply quality, which makes it more versatile. The key focuses of this approach are the resolution of problems and the improvement of processes, both of which are driven by the data (Maleyeff and Kaminsky, 2018). The benefits of the framework are as follows: 1) It is uncomplicated and simple to comprehend; 2) Each step is appropriately integrated; 3) It is suitable for broad application; and 4) It gives a road map for the execution of its functions. In addition to this, the DMAIC methodology suggests a fundamental approach that may be of assistance to practitioners, as well as a variety of tools that are much more efficient.

2.4.2 5S

According to Carmichael, Mullen, and Mante (2017), the '5S' strategy is a vital tool in Lean manufacturing, and it may assist any company. The authors note that the approach was developed by Toyota. This is due to the fact that it encourages cleanliness and organisation. The 5Ss is an organisational strategy that helps get rid of clutter and waste by sorting things, putting them in order, shining them up, standardising them, and maintaining them in a consistent manner. Both minimising the amount of clutter in one's space and making sure that everything has a place to call its own are incredibly important. There is "a place for everything and everything in its place" in a workplace that adheres to the 5S methodology, which indicates that all of the required resources are easily accessible both when and where they are needed. This is known as the "a place for everything and everything in its place" adage. The idea of "5S" is frequently explained using the idiom "a place for everything, and everything in its suitable place," which may be found in a variety of settings. You may be aware with the technique of cleaning and organising known as "KonMari," which was developed by Marie Kondo and popularised by her daughter after the elder Kondo's passing. Through the use of the KonMari technique, congested homes may be cleared out and simplified, which, in the end, leads to living circumstances that are less chaotic and more well-organized. The concepts that underpin 5S are very similar to those that underpin the KonMari method of organisation. On the other hand, to suggest that yoga is solely concerned with stretching is comparable to arguing that yoga is only concerned with arranging poses in certain sequences. In light of this, let us investigate not only the fundamental goal of the 5S system but also the significance of it. The abbreviation 5S was created by combining five distinct phrases from the Japanese language. Seiri, Seiton, Seisou, and Shitsuke are just a few of the terms in this category. Some of the names that have been used to refer to them in English include the following:

1) Sort: Get rid of anything that isn't completely necessary at this point.

2) Straighten: When you have finished sorting everything, the following step is to straighten up what is left and arrange everything in order.

3) Give It a Shine: Make certain that the location in which you do business is immaculate and thoroughly examine it.

4) Standardize: Create a set of criteria that must be adhered to while doing the 5S.

5) Sustain: It is imperative that the 5S standards be adhered to at all times.

Activities based on the 5S methodology, which help instil the discipline necessary for considerable and ongoing development, are at the centre of the process of establishing (and maintaining) efficient and productive working environments. This is one of the most important aspects of initiating and maintaining 5S activities.

2.4.3 Root Cause Analysis

Root cause analysis is a structured team process that assists in identifying underlying factors or causes of an adverse event or near-miss. Understanding the contributing factors or causes of a system failure can help develop actions that sustain the correction. Waste in production may be caused by issues that keep occurring. Waste in the form of downtime for machines, reworked products, increased scrap, and the time and money spent "solving" the issue. We may often assume that the problem has been fixed when, in fact, all we have done is treat a symptom of the issue rather than the true core cause of the case. If it is carried out accurately, a Root Cause Analysis can identify flaws in your procedures or systems that were a contributing factor in the non-conformance and determine how to stop it from occurring again in the future. An investigation called a RCA is carried out to figure out what went wrong, why it went wrong, and what kind of adjustments or improvements are necessary. The implementation of RCA in an appropriate manner makes it possible to eradicate recurring issues.

The use of RCA techniques and tools is not restricted to addressing problems that are unique to the manufacturing process. The RCA technique is being used in various contexts across many different sectors, and this organized style of issue resolution is also being used. The following are some instances where RCA is being employed. However, this list is not exhaustive for office workflows and standard operating procedures, concerns regarding quality control, incident analysis in the healthcare industry, analysis of hazardous events or safety-related scenarios, analysis of failed policies in engineering and maintenance, and activities related to either change management or continuous improvement, examination of computer systems and software. The idea is that RCA can be used for almost every different kind of issue that businesses deal with daily. A further scenario in which RCA may be useful is when a corporation deals with an unusually large number of inaccurate client orders and shipments. The procedure may be drawn out and examined, and the underlying issues causing the difficulties can be identified and fixed. The final result is a client base that is satisfied, loyal, and pleased, as well as total cost reductions for the organization. Conducting a root cause analysis may be done using a variety of methods, approaches, and techniques, such as events and causal factor analysis, frequently utilized for major, single-event problems such as an explosion at a refinery. This method uses evidence gathered on time and systematically to establish a timeline for the activities that led up to the accident. After the chronology has been constructed, the elements that have been determined to be causative and those that have contributed may be determined. Second, change analysis is a method that may be used in circumstances in which the performance of a system has undergone considerable transformation. It investigates alterations made to people, equipment, information, and other factors, all of which have the potential to have contributed to the change in performance. Third, barrier analysis is a method that focuses on the controls already in place to either avoid or identify a problem, as well as the controls that may have failed. Fourth, management supervision and risk tree analysis are two aspects of the same strategy. One component of this strategy is using a tree diagram to investigate what happened and the possible reasons why it happened. Last, Kepner-Tregoe's Approaches to Solving Problems and Making Decisions. This model includes the following four stages in the process of issue resolution to analyze the situation, the analysis of the problem, solution analysis and analysis of the possible problems.

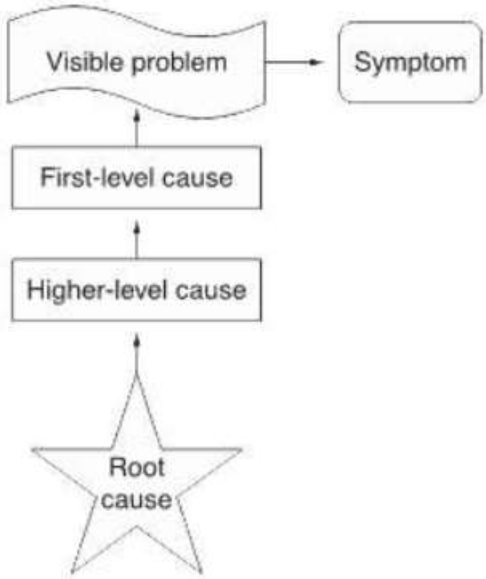

Figure 2.1: RCA diagram

2.4.3.1 Fishbone

The fishbone diagram, also known as the Ishikawa diagram, is a cause-and-effect diagram that is used to assist managers in determining the factors that contributed to failures, variations, faults, or defects. This kind of figure is also known as the Ishikawa diagram. Ishikawa diagram is another name for this kind of figure that may be used interchangeably. Figure 2.2 is an example of a diagram that has been constructed in such a way that it gives the impression that it is the skeleton of a fish. The issue is symbolised by the "head" of the structure, and the elements that led to the issue are shown by the "spine" of the structure. When all of the underlying causes of the problem have been identified, managers may begin investigating potential solutions to the topic in order to be certain that it will not become a problem that happens again in the future. It is also conceivable to apply it to the process of manufacturing things utilising it, which is something that is achievable. If people are concerned about the question you are trying to solve, having a product that already addresses the problem will increase the likelihood that the target audience will favourably receive your most recent design iteration. The purpose of the fishbone diagram is to identify every issue that exists with the products and services that are already for sale on the market so that you may create something new that does not have these issues. This will allow you to better serve your customers. Utilizing the diagram will allow you to successfully complete this task. In conclusion, but by no means in the least, the fishbone diagram is a helpful tool for recognising potential issues with product quality far in advance of the time when they really manifest themselves. If you use it to do troubleshooting before an issue emerges, you should be able to handle the most, if not all, of the teething problems you have when introducing anything new.

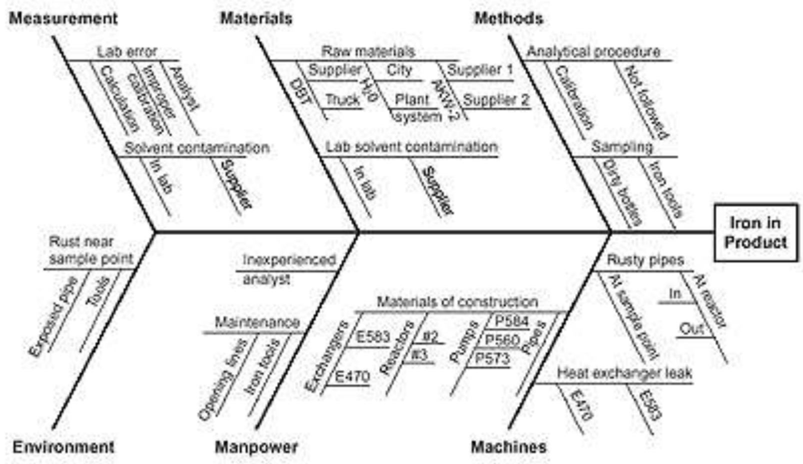

Figure 2.2: Fishbone diagram example

2.4.3.2 5 Whys

In the 1930s, Sakichi Toyoda, the man who would later form Toyota Industries Corporation, came up with the idea that would become known as the "5 Whys." Taiichi Ohno, who was the creator of the Toyota Production System and popularised the 5 Whys concept, was responsible for bringing the idea to the attention of the general public later on in the 1950s. Ohno is widely regarded as one of the early pioneers of the Lean thinking methodology, in addition to the significant part he played in the development of Toyota's manufacturing process. Within the pages of his book titled Toyota Production System: Beyond Large-Scale Production, he explored the 5 Whys of Lean. In it, he presented the concept as "the cornerstone of Toyota's scientific approach," which was described as follows; Toyota, as a firm, approached a significant portion of its problem-solving work with a "go and see" mindset. In other words, the leadership of the organization strives to make choices based on an in-depth knowledge of what is really taking place on the production floor, rather than depending on what executives or board room members believe may be taking place. It is not possible for the 5 Whys idea to be carried out successfully as a solitary or individual endeavour, which is one of the primary reasons why it calls for the active participation of members of the team. The idea behind the "5 Whys" is founded on a simple premise: Whenever an issue arises, one should inquire as to "Why?" up to the maximum of five times, or until a workable solution is presented. The 5 Whys is a method of problem-solving that was developed to assist businesses in determining the fundamental reasons behind an issue. The response to each subsequent Why question enables teams to investigate the issue in more depth, bringing them closer to determining not just the nature of the problem but also the appropriate solution. When it comes to troubleshooting things like product faults, general problem solving, quality control, or process improvement, the 5 Whys may often be of great assistance. The method is efficient for solving problems that range from easy to moderate in difficulty, but it is not as useful for solving difficult or urgent issues.

Five whys (5 whys) are problem-solving methods that explore the underlying cause-and-effect of particular problems. The primary goal is to determine the root cause of a defect or a situation by successively asking the question "Why?". The number '5' here comes from the anecdotal observation that five iterations of asking why is usually sufficient to reveal the root cause. In some cases, it may take more or fewer whys, depending on the depth of the root cause. In a production context, the 5 Whys method is especially successful since it can be used to identify the root cause of errors or poor quality swiftly. In addition, the approach has the benefit of fostering cooperation and collaborative problem-solving, among other things.

Furthermore, it is rapid, low-cost (just in terms of time), and since it is so basic, it takes very little training, which increases the likelihood of workers being committed. A practical application of the 5 Whys may include convening a group of people with complementary abilities and asking them to go through the 5 Whys for a previously identified issue. Documenting their thoughts, for example, on a whiteboard, is necessary for this process. A recommendation for doing so is that one drawback of the 5 Whys method is the possibility of going down an incorrect tangent, and hence drawing the false root cause conclusion if you are not accurate about the underlying cause for one of the Whys. Making a knowledgeable group is advantageous since it enhances the probability of receiving honest responses to the Why? Inquiries. This is partly because the group is more likely to recall concerns collectively and examine and scrutinize the answers to each 'Why?' query. The team should use several probing inquiries to investigate the replies and, as a result, identify the underlying problem. For example, one may inquire whether a wide variety of factors might result in the issue and what proof there is that the agreed-upon solution is the core cause. Also, has anything similar to this occurred before? It is also evident that the collective wisdom of those there will be of great importance. It is then possible for the group to begin suggesting viable remedies after the fundamental cause has been identified. These may then be evaluated in terms of cost, timeliness, and feasibility before being put into operation.

2.4.4 Visual Management

Visual management, an efficient decision-making tool, is an easy way of visual analysis and information display. When visual management is used with the 5Ss, it ensures that employees adhere to safe work practises, understand systems, do regular quality checks, and stick to instructions (Strategos-International, 2016). Virtual reality is fundamentally about human communication. A good VM employs natural visual cues that are easy to recognise and memorise in order to communicate crucial workplace information. Although VM may be used to communicate any kind of data, it is most often used to show information concerning, among other things, standards, expectations, and warnings. The essential element to remember is that this information may be conveyed visually without any further explanation. Therefore, regardless of my familiarity with the workplace, I should be able to navigate the area, monitor the team's progress toward the objective, and see the present status of the job in real time. Visual Management should be used to guarantee that all important information in a workplace is simply understandable, since each VM conveys a clear message at a glance. It is essential for maximising the advantages of lean, and it may increase efficiency while engaging and inspiring the whole team to deliver better outcomes. Keeping the "continual" in continuous improvement is also essential for progress. Beynon-Davies and Lederman's (2017) proposal to use the affordance theory as an explanatory lens is, as far as is known, the only substantial attempt to theorise about VM.

In 1977, Gibson provided an outline of the affordance theory. Fundamentally, affordance relates to what the environment affords a human or animal. These, in turn, need supplementary efficacies in the form of mental or physical abilities. According to BeynonDavies and Lederman's definition, an affordance is an opportunity for action that is enabled by both the effectivities of an actor and the structures of the environment (2017). They identify three levels or domains — articulation, communication, and coordination — that are interrelated via the affordances of visual technology. This definition is based on an examination of actual cases. Beynon-Davies and Lederman (2017) agree that Gibson's concept of affordances falls short of describing what takes place in virtual reality (VM). They utilise the words affordance and affordances to differentiate between first-order affordance, which explains how the articulation of physical objects aids communication, and second-order affordance, which connects linguistic engagement with coordinated labour activities. Four aspects encapsulate Beynon-Davies and Lederman's (2017) description of visual devices within broader visual systems: (1) These systems rely on tangible, typically highly visual artefacts for information; (2) the physical manipulation of such artefacts with respect to one another is essential for informing actors during group work; (3) the general condition of the physical environment in which such manipulation occurs is also essential for informing actors; and (4) the manipulation of tangible, typically highly visual artefacts is essential for supporting situated choice. On the basis of their theoretical work, Beynon-Davies and Lederman (2017) present five suggestions for developing VM; alas, a synopsis cannot do these proposals justice. (1) Visual devices should be considered multimodal, employing all senses; (2) Visual devices should facilitate action-taking; (3) Physical structures, such as whiteboards, should be considered performative structures (how to communicate and what work would result from such communication); (4) The designer of VM should not focus on a single device but rather the entire physical environment; and (5) Action patterns should be taken into account (this essentially refers to embracing current status, targeted status, and change in the development of visual Management).

Even if lean manufacturing is popular and the majority of organisations want to use it, lean practises will fail if there is a lack of understanding around lean success and its measures. Lean management cannot be implemented effectively without first analysing its effectiveness. This work describes a numerical model for assessing the lean performance of manufacturing systems. With this approach, it will be easier for managers and decision-makers to evaluate the system's efficacy and identify possible areas for improvement. Productivity enhancement methods may have an effect on existing lean manufacturing processes. In addition, business executives often lack a map of their own organisation, which may contribute to the failure of the lean principles. The lean brain concept is offered to provide leaders a more comprehensive picture. According to this theory, organisations are networks with distinct organisational structures, functional links, and dynamic patterns that promote productivity. In order to remain competitive, firms seek to improve quality and productivity while reducing expenses and cutting manufacturing times. They accomplished this by adhering to the lean production standards, despite the fact that quality is one of the most important elements of lean manufacturing. Typically, quality and lean are separated and collapsible divides. A case study was undertaken in three Norwegian manufacturing organisations to demonstrate that the effective integration of lean and quality requires two important characteristics. Initially, a high degree of process maturity is essential. Second, it takes time for manufacturing systems to attain their maximum capacity. In addition, cultural influences have a substantial effect on how significant success elements for lean manufacturing are perceived and implemented. A case study highlighted how waste could be avoided, work could be standardised, internal logistics could be improved, the workspace could be arranged, and the architecture could be altered in order to turn a conventional production model into a lean manufacturing one. By using lean principles, it is feasible to reduce labour expenses by up to 40 percent, save 30 percent of floor space, and speed up delivery times. Examining the everyday operations of a business that has effectively adopted the principles of lean production into the company's culture shows a pattern of regular managerial behaviours.

2.4.5 Value Stream Mapping

A value stream map is a method for categorising all product types into distinct groups. The process is shown visually to indicate the supplier, the customer, and the phases. These procedures are described in detail to help in the development of a future state map, which illustrates the ideal future layout of the process after the adoption of appropriate Lean adjustments. It aids in the visualisation, detection, and elimination of all sorts of waste (Conner, 2017:29). The mapping of value streams allows for the analysis of production flow, which starts with the original idea and goes through numerous manufacturing and production processes before ending with customer support. A value stream map, also known as a "value stream analysis" or "lean process mapping," depicts the flow of materials and information across the manufacturing process from the supplier to the consumer. VSM may be used to discover waste and simplify the manufacturing process. It is made up of a process flowchart, a chronology, and an information flow. A process map illustrates the activities and data connected with each process step visually. Using the accompanying timeline, you can observe how cycle durations differ depending on whether the product provides Value, which may help you discover waste. The information flow depicts the interactions and activities that occur between the phases of the value chain in more detail. A value stream map may be created using templates, flow software, a whiteboard, butcher paper, and post-it notes, depending on the conditions.

Value Stream Mapping necessitates the engagement of all key stakeholders to ensure the process's efficacy and efficiency. Senior management teams, production personnel, and process and line operators are all part of this group. It is reasonable to presume that managers and operators are well-versed in all aspects of their respective process stages. As a result, everyone will be able to offer critical feedback, enabling you to distinguish between actions that bring value and those that do not, allowing you to adjust the process. The goal of value stream mapping is to study and record each step of a manufacturing process in order to uncover and decrease or eliminate labour, time, and material waste throughout the manufacturing process. Any action that does not meet these three requirements is deemed waste since it adds no value to the overall system. Before constructing a value stream map, evaluate all of the processes and stakeholders involved, and visualise how one action connects to the others. Value Stream Mapping has three components: input, value-add, and output, but it does not track the many pathways that each process might take. VSM, on the other hand, follows a single component, service, or transaction through a process or, if necessary, a family of components, services, or transactions. Only one route of the value stream should be followed when picking a product or product family to map, coupled with considerations such as price, availability, and customer satisfaction. It is possible to produce a Value Stream Mapping map after describing the process's value and selecting the product or product family for Value Stream Mapping.

2.5 Existing Literatures Regarding the Relationship Between Lean Principles and Lean Tools

In this research, which took a documentary approach, the literature was reviewed in a methodical manner over the course of three distinct stages: first, the planning of the review; second, the review by selecting or summarising academic work or research; and third, the preparation of the results and discussion of the contributions that were discovered. (Tranfield et al. 2003). Web of Science, the Scientific Electronic Library Online (Scielo), Dialnet, and the Directory of Open Access Journals are four of the most prominent scientific databases (DOAJ). Dates were selected in order to guarantee the most recent findings that are capable of being useful in the context of this study. Due to the fact that operations management and industrial engineering are excellent or relevant topics for this study, a search was undertaken in carefully chosen journals in categories pertaining to those two disciplines.

In the databases, under the categories of paper title, summary, and key-word search, the terms "Lean principle" and "Lean tools" were looked up and explored. These terms allude to the processes that are used in manufacturing companies for the purpose of achieving continuous improvement. Across all of the databases that were searched, a total of 46 documents were discovered. The members of the study team initially went through each publication and evaluated it in order to determine whether studies particularly discussed the deployment of certain types of technologies to enhance retail operations and which papers did not touch this topic. In the end, a total of twenty (20) pieces of writing were chosen for the investigation.

2.6 Literature Finding

The future of the manufacturing industry is lean manufacturing, and lean manufacturing practises are among the most effective ways for enterprises throughout the world to increase their competitiveness. The future of the industrial sector is lean manufacturing. Toyota engineers developed a set of practises and methods known as lean manufacturing. It is a production strategy that is increasingly widely used in organisations today and strives to maximise product value by eliminating waste. Managers use lean techniques including quality, cost, just-in-time (JIT) delivery, and