SUSTAINABLE LEAN MANUFACTURING AND SUSTAINABLE PERFORMANCE: TOWARD THE CONCEPTUALIZATION, OPERATIONALIZATION, AND EMPIRICAL INVESTIGATION OF MNCS

By
MISS Juthamas BROMMANOP

A Thesis Submitted in Partial Fulfillment of the Requirements
for Doctor of Philosophy (INTERNATIONAL BUSINESS) INTERNATIONAL PROGRAM
Department of INTERNATIONAL BUSINESS
Graduate School, Silpakorn University
Academic Year 2020

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นางสาวจุฑามาส พรหมมาณพ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปรัชญาดุษฎีบัณฑิต

สาขาวิชาธุรกิจระหว่างประเทศ แบบ 1.1 ปรัชญาดุษฎีบัณฑิต

ภาควิชาธุรกิจระหว่างประเทศ

บัณฑิตวิทยาลัย มหาวิทยาลัยศิลปากร

ปีการศึกษา 2563

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By	Juthamas BROMMANOP
Field of Study	(INTERNATIONAL BUSINESS) INTERNATIONAL PROGRAM
Advisor	Assistant Professor Jantima BANJONGPRASERT , Ph.D.

Graduate School Silpakorn University in Partial Fulfillment of the Requirements for the Doctor of Philosophy

.... Dean of graduate school
(Associate Professor Jurairat Nunthanid, Ph.D.)

Approved by

.... Chair person
(Assistant Professor Sid Suntrayuth , Ph.D.)

.... Advisor
(Assistant Professor Jantima BANJONGPRASERT , Ph.D.)

.... Co advisor
(Assistant Professor Chalermporn SIRIWICHAI , Ph.D.)

.... Committee
(AMARA WEERAWAT , Ph.D.)

.... External Examiner
(Assistant Professor Santi Termprasertsakul , Ph.D.)

58502902 : Major (INTERNATIONAL BUSINESS) INTERNATIONAL PROGRAM
Keyword : lean sustainability; sustainability performance; lean social sustainability; lean economic sustainability; lean environment sustainability; MNCs

MISS JUTHAMAS BROMMANOP : SUSTAINABLE LEAN MANUFACTURING AND SUSTAINABLE PERFORMANCE: TOWARD THE CONCEPTUALIZATION, OPERATIONALIZATION, AND EMPIRICAL INVESTIGATION OF MNCS THESIS ADVISOR : ASSISTANT PROFESSOR JANTIMA BANJONGPRASERT, Ph.D.

Nowadays, many studies indicate the attention on the application of lean manufacturing in sustainability. Indeed, the role of lean has played an important role in achieving sustainability outcomes. Specifically, previous research has shown the relationship between lean and sustainability in many business areas. Despite the critical effect of lean on sustainability performance, there are only a few studies that provide well-established empirical evidence. Furthermore, there is little insight in the effect of lean manufacturing on sustainability. Thus, the purpose of this study is to investigate the effect of lean sustainability practices on sustainability performance in MNCs in automotive manufacturing sector. A quantitative survey methodology was adopted to collect data by using questionnaire from 406 MNCs' workers in automotive manufacturing sector, Thailand. The findings indicate that lean sustainability practice composing three dimensions, lean social sustainability, lean economic sustainability and lean environment sustainability, have positive effects on sustainability firm's performance. The most influence dimension on sustainability are lean environment sustainability followed by lean social sustainability and lean economic sustainability respectively. The implications of the findings and suggestions for future research are discussed.

ACKNOWLEDGEMENTS

Because I owe it all to my life-coach, my dear buddy Marco Benini, for constantly encouraging and enthusiastic. He was always curious about what I was doing and how things were going. I'll miss your enthusiastic cries when a big milestone was accomplished, as well as your overall care. Thank you very much!

I am grateful to my parents and sister for their moral and emotional support throughout my life. It was sad that my father did not live to see me finish with a PhD because he passed just as I began my studies. I owe a debt of gratitude to my aunt, Associate Professor Dr. Thida Boontharm, and other family members for their unwavering support.

With a special mention to my advisor Assistant Professor Dr. Jantima Banjonprasert to be with me for six years with your unbelievable patient support and advise. It was fantastic to have the opportunity to work with you.

My heartfelt thanks goes out to Mr. Gareth Hughes, Managing Director of RSM (Thailand) Limited, who has always been by my side and helped me with all things English!

I am also grateful to the following university staff: Ms. Aoh Monthicha and Ms. Nong Rinyarat for their unfailing support and assistance to all paper work and iThesis processing.

And finally, last but by no means least, also to sister Jueoy, Bee Patcharin, sister Minnie Ms. Kamonluk ,brother Top Mr. Suraporn, PhD classmate and everyone friends in Grundfos, in the impact hub… it was great encouragement from all of you during last six years.

Thanks for all your encouragement!

Juthamas BROMMANOP

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Many businesses, notably those in the automotive industry, battled in the new client, world class economy. This puts firms under a lot of pressure to find new tools and strategies to deal with rapidly changing markets. To overcome this situation and to increase profits, many factories apply “lean manufacturing” (LM) in their operations. An example of lean manufacturing practice in organization is the Toyota Motor case. Following WWII, Toyota realized that a succession of basic advancements could make it easier to have both process continuity and a wide range of product options. As a result, they went back to Ford's original idea and created the Toyota Production System. In essence, this method redirected the factory engineer's focus away from specific devices and their usage and toward the flow of the production through the entire process. Toyota came to the conclusion that by right-sizing machines for the real volume required, adopting self-monitoring equipment to increase security, aligning machines in process order, and inventing rapid setups, they could achieve their goals that each equipment could create small quantities among many part numbers, and having each procedure step alert the preceding phase of its current demands for materials, it'd be able to attain low cost, vast selection, high quality, and very speedy throughput times to react to changing consumer desires. Also, knowledge management may be made much easier and more precise.

Toyota was already in its invention of the Toyota Production Approach (TPS) and the inventor of the Lean system, and it was on its way to displace the rest of the planet in terms of creating reliable, high-quality automobiles. Academics, scholars, and professionals interested in benchmarking Toyota TPS or LM have been lured to the firm. (Stone, 2012, Liker, 1997, Womack et al., 1990). There are several reasons to benchmark with Toyota. First, Toyota urged workers to participate in the manufacturing process. Quality circles, a group of employees that convene to explore workplace development, were developed by the corporation. Members of the quality circle provide comments to management about quality and performance. Second, Toyota devised a series of operations that cut setup and changeover times in half. As a result, Toyota created smaller batch assembly, which necessitated a set of techniques that cut setup and changeover times. The process that resulted was called Single Minute Exchange of Die (SMED). Other Japanese companies embraced Toyota's innovations, although none were as effective as Toyota's. In the 1980s, American businesses learned to incorporate some of Toyota's practices and Continuous Flow Manufacturing (CFM), World Class Manufacturing (WCM), and Stockless Production are some of the terms used to describe these processes (Ohno, 1988, Kaisha and Kaisha, 1988, Morgan and Liker, 2006).

However, Global warming, inequality and unfairness, population increase, pollution, and the rising cost of energy and resources are all major concerns in the business sector. Customers, authorities, and other partners are pressuring businesses around the world to deliver their services responsibly to increase company environmental and social practices. As a result, enhancing sustainable development and decreasing the negative environmental and social effects of industrial operations has become a corporate imperative: sustainability has become an unique disruptive criterion (Turley-McIntyre et al., 2016, Rusinko, 2007, Young and Dhanda, 2012). According to (Chiarini, 2014) By use of management solutions to solve the fundamental global sustainability challenge has been investigated. In this environment, LM has emerged as a critical component of the sustainability solution. The fact that lean manufacturing is defined as using less, or the bare minimum, of just about everything required to manufacture a product or provide a service. (Hayes and Pisano, 1994). This concept "lean" refers to a system that uses fewer resources (in terms of all inputs) to produce the same results as a standard mass production system while offering more variety to the end user. (Womack and Jones, 1997). Likewise, sustainability production requires a commercial activity in the manufacturing industry that encompasses all of a company's strategies and policies in the framework of social and natural communities in which it operates and impacts, with the explicit goal of minimizing and minimizing any bad impacts while maintaining the desired level of economic and technological efficiency. (Richardson et al., 2009). LM Given a chance to decrease waste, increase productivity, and positively correlated, sustainable projects should become a deliberate goal. Thus, LM is important to sustainability production performance achievement (Fliedner, 2008).

Production firms have been paying attention to lean manufacturing and sustainability in particular over the last decade, as increased pressures from government, regulatory organizations, and society have prompted corporations to align business operations with environmental sustainability principles. There are numerous reasons for businesses to implement these two ideas, as they provide various benefits on the corporation as a whole.

The study of Japanese manufacturing practices, particularly in the automobile industry, gave rise to the notion of lean manufacturing (Womack et al., 1990). Lean manufacturing refers to a set of methods that affect nearly every element of a company's operations. Practices relating to technological and human capabilities, as well as workplace management, are at the heart of it. (MacDuffie and Helper, 1997). Lean manufacturing reduces and removes waste in processes by attempting to make value flow at the pull of the consumer (Just-In-Time). Transportation, Storage, Motion, Waiting, Over-processing, and Overproduction are among the eight wastes, Defects, and Non utilize talents (Womack et al., 2003). All of these wastes have a direct effect on business costs; they are all non-value-adding processes that customers would be unwilling to pay for and that add no value to the product or service. Furthermore, according to the first principle of Lean, acquiring satisfied customers involves identifying value as viewed by the consumer; if the company provides the consumer with what they expected, they will be satisfied. Implementing Lean allows the company to stay in business and perhaps grow (Angelis and Fernandes, 2012). One of Lean's main goals is to remove stock in production processes, which frees up cash flow for the business. (Abu et al., 2019).

According to (Charron et al., 2014), the lean theory, which has only been around for about 30 years, is a new concept to describe manufacturing process development practices. Based on how we classify lean, it also has a long tradition. Some trace it back to Ford and his manufacturing processes for the Ford Model T, one of the first mass-produced automobiles, letting Ford to achieve his goal of mass producing the universal automobile, and Eli Whitney, who posted the first streamlined rifles to the US government.

Ford did not create any of it, but when he first planned his production line for the Model T, he put several ideas together. He would not have been able to achieve his goals without the profitable Model T car, which for twenty years gave Ford the means to venture as no other industrialist ever has. (Ford, 1997). As a result, lean literature evaluations have become standard in most recent papers, with a common opinion on the accomplishments from many within Toyota, Henry Ford, and others (Kyle B. Stone, 2012).

Apart from Ford, Eli Whitney, who sent the first standardized rifles to the US government and thus became the concepts to produce muskets at the end of the 18th century that had been used as the ideas of making interchangeable parts before Ford, left his mark on the history of standardization as "the father of mass production for war purposes".

What Japanese including Deming, Juran, Shewhart, and the other advisors hired to assist them, Toyota and other Japanese corporations learnt the significance of quality and delighting their consumers. (Hendrickson III, 2014). They also realized how critical it is to include their entire crew in making changes. Quality and regard for their personnel become highly essential for Toyota. It also came up with methods and principles like CANDO (Clean up, Arrange, Neatness, Drive, Ongoing Improvements), which is now the foundation for their 5S approach. (Kaisha and Kaisha, 1988). Toyota responded and established the Just-in-Time (JIT) idea, which, along with Jidoka, comprised the two fundamental pillars of the emerging Toyota Production System (TPS). Just in Time has evolved into a Japanese process control concept that entails having the correct things in the right amount and quality in the right location at the right time, as well as Kanban systems (Cheng and Podolsky, 1996, Takagi, 1985) By the 1950s, the Toyota Production System (TPS) was well underway, and Toyota was it's on its way to outperforming the entire world in terms of creating dependable, high-quality automobiles (Kaisha and Kaisha, 1988) Shigeo Shingo established the Pokayoke (error proofing) approach in the 1960s, and Ishikawa created the Quality Circles idea, allowing Toyota staff a greater say in the company's destiny (Ohno, 1988). After Kanban solutions were carried out to suppliers in 1965, TPS was written down. 'Toyota instructs implicitly,' says Robert Hall. They can't explain what they're doing in words, not even in Japanese'*. TPS drew attention for the first time in 1973, during the first fuel crisis. The TPS was initially taught to academics in English (Sugimori et al., 1977). With the outstanding culture of continuous improvement (Ohno, 1988), Toyota developed a number of tools and approaches to minimize waste and improve production systems' leanness (Monden, 1998). Despite said to be effective at Toyota, many of the TPS methods were concern and difficult for operators to follow.

Because of the oil crises created the Worldwide Motor Vehicle Program at MIT was founded on a desire to learn more about the destiny of the automobile industry. (Holweg, 2007). After investigating the Japanese way of producing, primarily Toyota Production Systems (TPS), a research organization at MIT first defined the idea of creating goods in a 'lean' manner in the 1980s (Womack et al., 1990). They provide Lean manufacturing in a methodical manner and describe five key parts of lean implementation, including value, value stream, flow, pull, and pursuit of perfection. To starting with, the concept "leanness" has been carried out in a variety of ways across the research (Mason-Jones et al., 2000) use the term 'leanness' is used to describe the process of putting lean concepts into practice. Today, Lean is gaining traction both in all region on the globe, and in Europe. Large organizations are adapting and implementing lean concepts outside of industry. Given the fact that lean manufacturing began in the Japanese automobile and automotive industries, it has gained favor in not only the United States but also in other countries. Lean concepts are spreading throughout industries, from logistics network to retailing, building, and even medical and federal agencies. The goal is to improve operational efficiency at all levels of organization by eliminating any unproductive or unneeded processes. The most pressing issue today is the administrative question of which tools and principles to use.

As a result of global concerns such as the energy crisis, recession, and climate disasters, the sustainability movement has grown in relevance. The possibility of societal transformation progress toward a more fair and wealthy society where the natural environment and cultural context are valued, protected for future generations is encapsulated by the term "sustainability." (Dyllick and Hockerts, 2002). Furthermore, with another concern about the carrying capacity of natural systems, the current main concerns facing humanity become entwined. Although the concept of sustainability is intuitively grasped, putting it into tangible, operational terms remains difficult. (Briassoulis and Management, 2001). A platforms solution is proposed to include strategic sustainable development planning at the firm level congruent with the core concepts and requirements for sustainability has been developed. (Roberts and Cohen, 2002). The approach thereby attempts to: 1) Address social and ecological sustainability at a fundamental level. 2) Take the concept of sustainable development and apply it to the organization. 3) Administer the strategic point of view in a step-by-step manner, taking into consideration economic results in terms of both short- and long-term risks. 4) Encourage the creation of indicators that reflect this viewpoint, and 5) Demonstrate how diverse actions in this field connect to a conclusion suggests on sustainability. (Labuschagne et al., 2005).

The proposed synergy of the available instruments, on the other hand, does not effectively support judgement in the industry (at the company manager level) who must assess their practices in terms of internal and external consequences. Only when the economic, social, and environmental repercussions are taken into account can optimal judgments be formed. (Hockerts, 1999). As a result, there is a clear need to develop a comprehensive set of sustainability standards for the industrial sector, focusing on policies and procedures and, in particular, the examination of lengthy effectiveness of technical breakthroughs across project planning. (Warhurst and report, 2002).

Since the United Nations and national governments around the world have been at the forefront of sustainable development, most frameworks for assessing sustainability have concentrated on the national, regional, or community level. (Hass et al., 2002, Veleva and Ellenbecker, 2001). The concepts usually entail the three well-known characteristics of sustainable development. (From an economic, environmental, and social standpoint.)

As the notion grew in popularity, people became more interested in the role of lean manufacturing techniques in glanced up sustainability goals (Fliedner and Majeske, 2010, Garza-Reyes, 2015). In this research The research on how lean manufacturing may improve to sustainability results and turn operations into lean sustainability business practices has always been lacking. Without requiring explicit sustainability action, evaluating the fields of deployment will enable businesses to divert their attention to prospective areas for enhancing their sustainability performance. Nevertheless, almost all of the study has been focused on determining certain lean manufacturing and practices in isolation, such as lean management that eliminates waste all through the value stream of a product (Shah and Ward, 2003) , minimum amount of waste from JIT, maximize capacity utilization (Treville and Antonakis, 2006). Therefore, it is important to apply lean manufacturing in sustainability according to lean manufacturing can contribute to sustainability outcomes.

Several of the published content cover many aspects of businesses and the relationship between Lean and long-term manufacturing performance. Even though the motor industry accounts for more than half of academic research, lean has emerged globally in a wide range of industrial sectors, including electronics manufacturing, aircraft manufacturing, woodworking, ceramic industrial production, and more (So and Sun, 2010, Barbosa and Carvalho, 2014, Abu et al., 2019, Kleszcz, 2018, Sangwan et al., 2014, Bonavia et al., 2006).

Thailand's automobile sector has taken a vital influence. In 2019, it will produce 2.014 million automobiles. More over half of the output is sold domestically, with the remainder being exported. As a result, Thailand's automotive sector is rated 11th in terms of global car production and distribution (Thailand Automotive Institute TAl 2020). It also produces gross domestic product (GDP) at 4.1% (NSEB 2020). Thailand, the term “lean” is still limited in the field groups, and sustainability is relatively name familiar but also to perceive the real meaning and value of it still not widely. Nevertheless, one of the outstanding areas which lean & sustainability has been implemented and apply is in automotive industry. It can be seen as a trend setter for the lean and sustainability context in the country. In addition, Based on the success of the Toyota Production System, lean concepts and methods seem to be a reference for other Thailand manufacturing organizations. Despite its size, many businesses still fail to create lean in a way that is both effective and sustainable.

As such, in this research aim to focus in Thailand automotive manufacturing, since the majority of them are MNCs and there is lack of research on the application of lean manufacturing sustainability, especially in MNCs. The literature of lean management and sustainability comprising of three key aspects which are environmental or ecological, economic and social factors, called “triple bottom line” (Dyllick and Hockerts, 2002), are explained in Chapter 2 which this research aims to explore the application of lean on sustainability, which is proposed that it should bring about superior sustainability performance

a. Sustainability issue in Thailand

Thailand's present economic and social system remains vulnerable in the face of these problems, and its overall administration remains inefficient and opaque. As a result of increased internationalization, Thailand is facing increasing competition and risk as the globe moves forward towards a world without borders - free movement of people, products and services, investment, expertise, and vast amounts of data.

The Twelfth National Economic and Social Development Plan (2017-2021) was drafted at a time when the globe was undergoing fast change and integration, and Thailand was implementing adjustments as well. The concepts of the "Sufficiency Economy Philosophy" have and will continuing to be a critical component of growth plan since the Ninth Plan, as they drive the promotion of self-sufficiency.

The Office of the National Economic and Social Development Board (NESDB) followed the 20-year National Strategy framework (2017-2036), the state's Sustainable Development Goals (SDGs), the Thailand 4.0 Policy, and other reform objectives when developing the Twelfth Plan. In order to map out development paths and methods for achieving the “Security, Prosperity, and Opportunity” goals, and collaboration by a large cross-section of society was a key principle in the development of this Plan, according to the NESDB.

It identifies the goals for Thailand's progress over the next 20 years, and even some strategic issues and the key paths to achieving these goals In turn, the Twelfth Plan, in conjunction with other procedures and accompanying devices, will be a vital tool for energizing the implementation of the National Strategy. As a result, the Twelfth Plan establishes specific economic, social, and environmental goals that have to be achieved within the next 5 years. Therefore, the sustainability issue will become highly attentions in all business sectors.

1.2 Contributions of research

Society has viewed Lean Manufacturing (LM) as a solution to all these needs as it decreases waste not requiring extra resources. The integration of lean and sustainability could lead to a direct improvement in firm's sustainability performance of three aspects social, economic, and environment which the expectation of outcomes should contribute which lean manufacturing concern the most effect to sustainability performance. The manufacturing both existing and newly establish can apply the result as pertinent lessons to implement lean sustainability in their firm which confident to improve their sustainability performance. In terms of contribution to the academic field the investigation of model study of lean manufacturing effect to sustainability performance could give the guideline for any sectors interested in studying the relationship among them. Moreover, the outcomes of the study can provide an innovative model particularly in Thailand industry, which could be the evidence of new contribution for involved sectors.

1.3 Research questions

Thailand's economic growth has been mostly fueled by industrialization. Because most produced goods are exported, they generate a significant amount of revenue for the nation each year. Therefore, lean manufacturing become important needs to be applied to manufacturing companies to generate the better output.

Meanwhile, because sustainable business decision-making reduces risks, sustains business results, realizes the long-term attitude, and responds successfully to a constantly changing society, there is a growing need to evaluate businesses' sustainability performance from environmental, social, governance, and economic perspectives. To put it another way, the increased necessity for businesses to demonstrate their effect has resulted in a new demand: measuring the sustainability performance.

In latest days, an increasing number of multinational corporations and current business operations have expressed interest in establishing a branch or beginning a new business in Thailand. Thailand is now a second home for many global MNCs and a distribution network hub for major sectors since it is a regional trade center with various advantages. These overseas investment efforts have been made possible because to the streamlining of government legislation, a growing domestic market, and access to resources such as finance and technical knowledge. (https://www.boi.go.th/).

According to three important aspects the following research questions (RQs) have been formulated:

Research question1. What is the measurement scale of Lean manufacturing applied in social, economic and environment sustainability dimensions?

Research question 2. How the Lean manufacturing applied in social, economic and environment sustainability dimensions affect sustainability performances?

Research question 3. How do the research findings contribute and implicate in the multinational companies (MNCs)?

1.4 Research objectives

The target of this experiment is to investigate the following scenarios and identify the effects of lean manufacturing applied in social, economic and environment sustainability dimensions on sustainability performances in multinational companies (MNCs). The study further aims to examine how lean manufacturing could create the contributions and implications that Lean manufacturing has the potential to benefit them and help them enhance their businesses. The following are the primary aims of this study in order to address the research questions:

1. To develop the measurement scale of Lean manufacturing applied in social, economic and environment sustainability dimensions.

2. To examine the effects of Lean manufacturing applied in social, economic and environment sustainability dimensions on sustainability performances.

3. To identify the contributions and implications of the research findings in the multinational companies (MNCs).

1.5 Conclusion

The research is summarized in this chapter. The aim, objectives, and justification of the research topic was discussed. The purpose of this study is to look into the impact of lean manufacturing applied in social, economic and environment sustainability dimensions on sustainability performances in multinational companies (MNCs). It explores and investigates the new measurement scale of lean manufacturing applied in social, economic and environment sustainability dimensions. Furthermore, this research will analyze the gaps as LM and Sustainability has not been widely in empirical research and give a set of recommendations. The four possible chapters of this research will offer a full discussion and findings of the research issue, with all of the major areas of this chapter only touches on the research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature will be critically assessed in this chapter on topics such as: the concepts and needs of lean manufacturing, lean manufacturing practices and sustainability, and the principles and indicators of sustainability. The chapter aims to indicate the key aspects of lean manufacturing as well as various experts' work has been examined and discussed, which will aid in the development of the framework. It also points to the lean sustainability principles and lean sustainability practices includes a review of lean sustainability practices in three areas of environment, social and economic. Additionally, this chapter demonstrates the sustainability performance assessment frameworks and models developed by several researchers to help the framework design synchronize of lean sustainability practices and sustainability performance.

2.2 Overview of lean manufacturing

Production is the process of making goods by machine or by hand and then selling them to a customer. In the production process, manufactured goods or component pieces of a larger product would be used. The majority of manufacturing is done on a vast production line with specialist machinery and staff. (Kenton, 2005). The first manufacturing was started from the first industrialization lasted about two centuries. The introduction of steam engines, water power, and automation propelled the first industrial revolution, which took place towards the end of 1970s. The manufacturing plants, which were pioneered by Henry Ford, who first officialized mass production about a century ago, were then used to propel the industry forward.

Many people believe that manufacturing, regardless of the type of manufacturing utilized, is what drives the economic structure of every society on the planet. There are numerous techniques to producing that people use, as well as several factors to consider. Here's some background on some of the most major manufacturing theories. Because each firm produces something different in a different way with different personnel, each firm and even each factory has its own theory. The craft or guild system is a manufacturing philosophy that isn't widely employed any longer. This system, which dates back to the dawn of production, is now considered outdated and inefficient. However, some businesses are resorting to this kind of production due to the craft and worth of something handcrafted. This sort of production is usually of higher quality and costs more than other types of production. Many people believe that mass production is a given in any manufacturing operation, but this isn't always the case. This is a broader phrase that can refer to a variety of different sorts of manufacturing, but it is also the foundation for many systems. Manufacturing and economics in general rely heavily on the principle of producing more in less time with less money.

Productivity and efficiency are two crucial ideas in manufacturing that must be constantly monitored. In industrial, productivity is measured as the number of output to input, and it is a measure of efficiency for increasing the number of items produced in the same unit of time. This results in an improvement in production. Increasing efficiency can also contribute to increased productivity. This can be accomplished by investing in automated manufacturing equipment, enhancing logistics, hiring more trained workers, and using lean manufacturing practices. Productivity rises when the line goes quicker. (Kenton, 2005).

Many people are aware with the term "lean manufacturing," which refers to a method of eliminating waste throughout the production process. This involves waste of material in the manufacturing process, as well as waste of time, space, and other resources used in the manufacturing process, such as effort. Many businesses incorporate this concept into their manufacturing processes because they believe that eliminating waste improves the bottom line and allows for more profits through increased efficiency.

Lean Manufacturing and the theory of constraints (TOC) are two popular business theories that have gotten a lot of attention in recent years (Moore and Scheinkopf, 1998). The theory of constraints (TOC) is a management paradigm that considers any manageable system to be constrained by a small number of restrictions in accomplishing more of its objectives. There is always at least one limitation, and

TOC uses a focused process to discover it and rearrange the organization around it (Alvarez et al., 2017). The adage "a chain is only as strong as its weakest link" is adopted by TOC. This suggests that processes, organizations, and other things are susceptible since the weakest person or portion can always damage or break them, or at the very least have a negative impact on the end result. The Theory of Constraints is based on the idea that every process has a single constraint, and that improving the constraint improves the whole process throughput. A key implication of this is that optimizing non-constraints will not yield substantial results; only improvements to the constraint would advance the aim (achieving more profit). As a result, TOC aims to maintain a laser-like focus on improving the current constraint until it no longer restricts throughput, at which point the attention shifts to the next constraint. The fundamental power of TOC comes from its capacity to produce a laser-like concentration on a single goal (profit) and remove the main roadblock (the restriction) to achieving more of that objective. In fact, Goldratt considers focus to be the essence of TOC.

The Five Focusing Steps of the Theory of Limitations provide a particular process for finding and reducing constraints. It's a cyclical process, as depicted in the diagram below. The next sections go over the Five Focusing Steps in further detail (Cox III et al., 2010). Identifying the current constraint is the first step (the single part of the process that limits the rate at which the goal is achieved). The second stage is to use current resources to quickly enhance the throughput of the constraint. The third stage is to assess all of the other activities in the process to ensure that they are all aligned with and actually serve the constraint's demands. If the restriction still persists, the fourth stage is to assess what more measures can be made to eliminate it as a limitation. Normally, operations are carried out until the limitation is “broken” at this point (until it has moved somewhere else). Capital investment may be required in some instances. The final step is concentrating, which is part of a cycle of continual improvement. As a result, whenever one restriction is handled, the following constraint should be handled right away. This phase serves as a reminder to never become complacent always strive to improve the current limit before moving on to the next. Both the Theory of Constraints and Lean Production are systematic approaches to increasing manufacturing efficiency (Dettmer, 2001). They do, however, take very different ways. The Theory of Restrictions focuses on finding and reducing throughput constraints. As a result, successful application tends to boost production capacity. The goal of lean manufacturing is to eliminate waste from the manufacturing process. As a result, effective application tends to lower production costs. According to (Sproull, 2012)Both techniques have a heavy emphasis on the customer and can help businesses become faster, stronger, and more agile. Despite this, there are considerable discrepancies, as seen in the following paragraphs.

Tables 1 The Theory of Constraints and Lean Manufacturing

What	Theory of Constraint	Lean Manufacturing
Objective	Strict attention to the limitation (until it is no longer the constraint).	The removal of waste from the production process is a major priority.
Focus	Strict attention to the limitation (until it is no longer the constraint).	The removal of waste from the production process is a major priority.
Result	Manufacturing capacity has been increased.	Manufacturing costs are lower..
Inventory	To maximize throughput at the constraint, keep enough inventory on hand.	Almost all inventory should be eliminated
Line Balancing	To increase throughput at the limitation, create an imbalance.	To get rid of garbage, find a balance (excess capacity).
Pacing	The tempo is set by the constraints (Drum-Buffer-Rope).	The pace is set by the customer (Takt Time).

Maintaining a degree of extra capacity for non-constraints is more feasible and less expensive than attempting to eliminate all causes of variation, according to the theory of constraints. In TOC, reducing variance is still desirable; it just gets less emphasis than increasing throughput.

2.3 Benefits of Lean

Lean gives a means to do even more with less and less—less physical endeavor, less tools, less duration, and less space—while getting closer and closer to delivering exactly what customers want. It also provides a way to make the job more gratifying by giving instant results on actions to turn muda (waste) into value. (Womack et al., 2003) p.15). Understanding the advantages of lean manufacturing and techniques provides manufacturers with a strategic advantage by lowering costs and increasing productivity and quality (Bhamu et al., 2014). Lean manufacturing will be used as a solving tool for aforementioned problems in the long-term perspective (Bhasin and Burcher, 2006).Lean manufacturing (LM) is : to build a new products in half of that time, employ half the personal interaction in the facility, half the manufacturing area, half the cost in tools, and half the technical working hours. It also necessitates storing significantly less than half of the inventory on site, which results in fewer flaws and a higher and steadily improving product quality. (Womack et al., 1990). There are numerous other advantages to adopting lean. For example, organizations can influence the efficiency of Lean implementation by integrating existing HRD expertise such as organizational development, learning, training, and creation with process and product advancement knowledge from operational activities and corporate development professionals (Alagaraja, 2014). According to (Wilson, 2010) p.71) The concept of long-term expansion providing value to customers, society, and business is at the center of Lean, with the goals of lowering costs, decreasing delivery times, and enhancing quality, all while eliminating waste. Nevertheless, these benefits cannot be accomplished unless the organization pay attention the important issues involved in LM. As mention above before going to within the specific organization requirement, principles and tools for LM, there is a need to understand the eight wastes that are the lean objective to eliminate which the organization can measure them and find where they are coming from.

2.4 Definition of lean

There is no consensus on what constitutes lean manufacturing. Overall, the studied literature indicates that lean manufacturing is not precisely defined (Jostein Pettersen, 2009). Because of the misunderstanding of what lean means, a variety of implementation techniques have emerged, particularly in terms of comprehending the precise meaning of lean and how it should be applied (Kyle B. Stone, 2012). Table 2 summarizes the many perspectives on Lean manufacturing advanced by various writers.

Tables 2 Lean Manufacturing definition
Source : (Jaiprakash Bhamu & Kuldip Singh Sangwan, 2014)

Author(s)	Lean Manufacturing Definition
1. (Krafcik, 1988)	When comparing to large scale production, it uses half the skilled workers in the plant, half the industrial area, half the expenditure in tools, and half the engineer hours to innovate new in half the time. It also demands keeping less than half of the required inventory on site, produces much fewer faults, and produces a bigger and the ever selection of things.
2. (Womack et al., 1990)	Lean is a proactive transformation strategy guided by a set of principles and activities that aspires for continuous improvement. LM blends the greatest aspects of both mass and handcrafted manufacturing.
3. (Womack and Jones, 1997)	Lean production can be considered a better integrated model since it integrates numerous tools, processes, and tactics in product development, supply management, and operations management into a coherent whole.
4. (Hayes and Pisano, 1994)	In an essence, lean is defined as using the minimum required of resources to create a product or provide a service.

5. Womack and Jones (1996)	The word "lean" refers to a system that uses less resources overall to provide the same outputs as a standard mass production system while offering more variety to the end consumer.
6. (Liker, 1997)	A theory that, when put into practice, lowers the time it takes from client order to delivery by eliminating waste in the manufacturing process.
7. (Cooper, 1996)	Lean production is a method of competing based on the notion that continuous product advantage is rare, thus rather than avoiding competition, it is confronted head-on.
8. (Dankbaar, 1997)	By assigning workers many tasks, combining direct and indirect labor, and fostering continuous improvement activities, lean manufacturing maximizes the utilization of workers' skills. As a consequence, compared to typical mass manufacturing, lean manufacturing may produce a wider range of items at lower costs and greater quality with less of each input: less human labor, less space, less investment, and less development time.
9. Cox and Blackstone (1998)	Lean production is a manufacturing concept that focuses on minimizing the quantity of all resources (including time) spent on numerous projects operations of the business. It entails identifying and reducing non-value-added tasks in design, manufacturing, supply-chain management, and customer service. To produce a huge number of potentially diverse commodities, lean manufacturers employ inter teams at all levels of the organization, as well as highly adaptive, increasingly automated technologies.
10. (Singh and Singh, 2013)	Lean manufacturing is a theory based on the Toyota Production System and other Japanese management techniques that aims to reduce the time between a customer's purchase and the completed product's shipment by eliminating waste on a

	continuous basis.
11.(Naylor et al., 1999)	Leanness entails creating a value stream that eliminates all waste, including time, while maintaining a consistent timetable.
12. Storch and Lim (1999)	Lean manufacturing is a cost-effective technique to meet client demands while also offering businesses a competitive advantage.
13. Howell (1999)	The goals and methods used on the job site, in design, and across supply chains to maximize production performance of the system against a standard of perfection in order to meet unique customers' needs distinguish this new way of designing and making things from mass and craft systems of capital.
14. Framework of the Lean Advancement Initiative (MIT, 2000)	[y] not being essentially a collection of factory-floor procedures. Lean is a fundamental shift in how people perceive and value things in an organization, resulting in a shift in how they act.
15. Comm and Mathaisel (2000)	Lean is a mindset aimed at lowering costs and shortening cycle times across the whole value chain while also improving product performance. There are several linkages in this value chain. There are connections inside government and business, as well as between government and industry.
16. Liker and Wu (2000)	A production philosophy centered on producing the highest quality product on time and at the lowest possible cost.
17. Cooney (2002)	Lean manufacturing takes a comprehensive view of manufacturing and distribution, producing a production philosophy that includes the whole manufacturing chain from product design and development through manufacturing and distribution.
18. Shah and Ward (2003)	Lean manufacturing is defined as a method of providing maximum value to consumers by eliminating waste through operational and behavioral design considerations. Just-in-Time (JIT), quality systems, work teams, cellular manufacturing, and other lean manufacturing approaches have grown into an integrated solution with numerous interrelated pieces and

	management techniques.
19. Alukal (2003)	Lean manufacturing is a production concept that eliminates all types of waste to reduce the time it takes for a client to place an order and for products or parts to be delivered. Lean assists businesses minimize costs, cycle times, and non-value-added processes, leading in a company that is more competitive, nimble, and market responsive.
20. Hopp and Spearman (2004)	Lean manufacturing is an integrated system that produces goods and services with low buffering costs.
21. Haque and Moore (2004)	By definition, lean is an enterprise strategy that uses a uniform framework for all business activities with the single strategic aim of reducing waste and increasing value flow.
22. Rothstein (2004)	Lean manufacturing is more commonly thought of as a broad production paradigm that encompasses a wide range of manufacturing systems that incorporate some form of lean manufacturing, for example Just-in-time inventory management systems, cooperation, versatility, employee involvement schemes, and procedures to ensure product quality all through production process are just a few examples.
23. Worley (2004)	Lean manufacturing is described as the systematic reduction of waste from all sections of the value stream by all members of the business.
24. Simpson and Power (2005)	Lean is a method for creating an efficient and well-organized system that is committed to continual development and the elimination of all types of waste.
25. Seth and Gupta (2005)	Lean manufacturing is a shift in thinking in manufacturing centered on the core aim of continually reducing waste while increasing flow.
26. Taj and Berro (2006)	Lean manufacturing is defined as “production without waste.” The lean strategy focuses on minimizing waste (Muda) in the value stream in a systematic manner.

27. Narasimhan et al. (2006)	Manufacturing is lean if it produces as little waste as a result of poor planning, unproductive activities, or wasteful buffering.
28. De Treville and Antonakis 2006	By reducing system variability, an integrated production system is designed to enhance capacity utilization and reduce buffer stockpiles.
29. Shah and Ward (2007)	Lean is a management style that focuses on finding and reducing waste throughout a product's complete value stream, which includes not just the organization's internal operations but also the whole supply chain network.
30. Holweg (2007)	Lean manufacturing broadens the scope of Toyota's manufacturing philosophy by defining an enterprise-wide phrase that encompasses all five elements: product development, supplier management, customer management, and policy emphasis.
31. Hallgren and Olhager, 2009	Lean manufacturing is a program that focuses on improving operational efficiency.
32. Taj and Morosan (2011)	A custom approach to procurement performance that combines minimal waste generation (JIT), continuous and uninterrupted flow (Cellular Layout), possibly the best machinery (TPM), a well-established quality system (TQM), and a well-trained and empowered work force (HRM) (quality, cost, fast response, and flexibility).
33. Alves et al. 2012	Lean production is defined as a paradigm in which people take on the importance of intellectuals, and their participation encourages continuous improvement and offers the adaptability they require today's and tomorrow's market needs and environmental changes.

As a first step, it's critical to comprehend the meaning of lean. According to the above definition of Lean Manufacturing (LM), many writers have differing perspectives on which qualities should be linked with the lean concept. The principles

(Table 3), shifting aims (Table 4), and scope (Table 5) are all reflected in this lean definition (Table5).

Tables 3 Definition of lean manufacturing based on principles

Lean Definition by principles	Appears in the reviewed literature																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A way	*	*																							
An approach					*																				
A manufacturing paradigm																							*	*	
A program																						*			
A philosophy							*	*	*	*	*	*	*	*	*										
A set of principles			*																						
A model																									*
A concept						*																			
A practice																*	*								
A process			*																						
A system																		*	*	*	*				
A set of tools and techniques				*																					

Note: (1) Storch and Lim, 1999; (2) Howell, 1999 ; (3) Womack et al., 1990 ; (4) (Bicheno, 2004 (5) (NIST 2000,Taj and Morosan, 2011; (6) Naylor et al., 1999 ;(7)Liker, 1996; (8)Cox and Blackstone, 1998; (9) Singh, 1998;(10) Comm and Mathaisel, 2000;(11) Liker and Wu, 2000; (12)Alukal, 2003;(13) Holweg, 2007;(14) Shah and Ward, 2007; (15)De Treville and Antonakis, 2006; (16)Framework of the LAI, MIT, 2000; (17)Simpson and Power, 2005; (18)Womack and Jones, 1994;(19) Cooper, 1996;(20)Shah and ward, 2007; (21) Hopp and Spearman, 2004; (22)Hallgren and Olhager, 2009; (23)Rothstein, 2004; (24)Seth and Gupta, 2005;

(25)Alves et al., 2012

Tables 4 LM implementation goals include a variety of objectives.

Various goals of LM	Appears in the reviewed literature									
	1	2	3	4	5	6	7	8	9	10
To obtain a wide range of fever-related items	*									
Product development, supply chain management, and operations management must all be integrated.		*								
To save costs/produce more with fewer resources			*							
To decrease the time it takes to provide				*						
To maintain a consistent manufacturing schedule					*					
To improve quality while lowering costs						*				
To eliminate waste from the system							*			
To increase throughput while reducing inventories								*		
To increase quality and productivity									*	
In order to develop agility										*

Note: (1)Krafcik, 1988); (2)Womack et al., 1990); (3)Hayes and Pisano, 1994); (4) Liker'™s, 1996);(5)Naylor et al., 1999),(6) Liker and Wu, 2000);(7)Worley, 2004);(8)De Treville and Antonakis, 2006);(9)Bhamu et al., 2012);(10)Alves et al., 2012)

Tables 5 The scope of Lean Manufacturing is classified.

Scope of Lean	Appears in the reviewed literature										
	1	2	3	4	5	6	7	8	9	10	11
Supply chain as a whole			*	*	*	*	*				
Paradigm shift in manufacturing									*	*	
Development of a product	*										
Aspect of human design								*			
Management of operations		*									
Changes in the market and the environment											*

Note: (1) Krafcik, 1988), (2)(Narasimhan et al., 2006); (3)Womack et al., 1990; (4) Singh, 1998; (5)Naylor et al., 1999; (6)Comm and Mathaisel, 2000; (7)Cooney, 2002; (8)Shah and Ward, 2003), (9)Rothstein, 2004; (10)Seth and Gupta, 2005, (11)Alves et al., 2012).

It is apparent that there is no universally accepted definition of the term. As a result, LM may be presented using any of the above definitions, based on the type of business that is required inside the individual company, and lean definitions that reflect shifting aims, principles, and scope.

A manufacturing paradigm, a practice, a method, and a collection of tools and methods are all typical descriptions in terms of principle in this study (Rothstein and Change, 2004, Seth* et al., 2005, Womack et al., 1990, Rebentisch and Rhodes, 2004, Simpson and Power, 2005a). In terms of research objectives, this thesis shares many of the same concerns as previous studies, such as having a wide selection of fever-related products, combining project management, supply chain management, and operations management, cutting costs/producing more with less, shortening delivery times balancing the manufacturing process, increasing quality at a cheap cost, and avoiding waste. In terms of the scope of the lean idea, this thesis builds on prior research on manufacturing paradigms and operations management.(Krafcik, 1988, Narasimhan et al., 2006).

2.5 Principles of lean

To adopt the lean system into any business, regardless of its size or industry, it must first grasp what lean is, how it benefits if it is accepted, what types of wastes it strives to eliminate, and the importance of understanding the lean principles. The following detailed explanation will go through the Lean concepts that must be thoroughly comprehended before beginning LM implementation. There are five LM principles, regarding (Womack et al., 2003) Specific value, identify the value stream, establish flow, respond to customer pull, and finally achieve perfections are the five principles of LM . These ideas could only be successful if they are followed. if focusing on not only quantity but also quality control system and lean firms, at least in the first several years of implementation, have to have a strong focus mature culture like Toyota (Wilson, 2010), p 32. Lean manages to focus on detecting and reducing waste across the product's entire value chain, not well within the company but across the entire supplier chain network, according to (Shah and Ward, 2003) The two essential ideas of Lean manufacturing, it has been claimed, are to remove waste and generate value (Fernando and Cadavid, 2007) (McManus et al., 2005, Emiliani, 1998). Finally, lean concepts are aimed at preventing and eliminating the eight wastes.

2.6 **There are eight wastes linked to Lean Manufacturing**

The wastes listed above are frequently also known as non-value-added activities., and they are referred to as the "Eight Wastes" by Lean practitioners. According to (Womack & Jones, 2010), Muda means "waste" in Japanese, and it refers to any human action that depletes resources while generating little value: Making errors that need to be solved, producing items that nobody ever wants, causing inventories and remaindered goods to build up, handling steps that aren't truly needed, moving workers and goods from one place to another after no reason, and groups of individuals in a down - stream activity trying to stand around waiting because an upstream activity is taking too long, and goods and segregation. Several acronyms for these Eight Wastes have been offered as memory aids, according to (Stack, 2012), but the one that appears to have caught on the best is DOWNTIME. It's plain, uncomplicated, and suitable. The following is a list of what each letter stands for: Excess processing, defects, overproduction, waiting, non-utilized/underutilized talent, transportation, inventory, motion Variations in procedures may be linked to waste. To combat such wastes, statistical methods such as the Six Sigma DMAIC (define, measure, analyze, improve, control) approach may be useful.

1) Excess Inventory

Avoid overproduction by balancing supply and demand. Overproduction occurs when items are produced in excess quantities or before they are required, resulting in surplus inventory. As a result of overproduction, this waste develops. This is a typical waste. Inventories are useless unless they are immediately converted into sales. It doesn't matter if Materials and work-in-progress are included in the stock, or finish goods. If it does not directly protect sales, it is a waste of time. (Wilson, 2010). It may have a harmful impact on the organization in terms of: tying up capital in stock, raw materials, work in progress (WIP), and finished goods, affecting cash flow; requiring valuable space for inventory storage and movement; requiring people and equipment to move it around, requiring additional work. All of this is a cost to the company; if they can eliminate it, the savings will go straight to the bottom line, increasing profits (Kilpatrick, 2003, Wilson, 2010).

Excessive inventory is caused by unreliable suppliers, mismatches in production rates, extended set-up periods (Womack et al., 2003), (Stack, 2012), and manufacturing more than required by most firms (Womack et al., 2003).

By implementing JIT and only manufacturing in response to direct client orders, the company may eliminate and decrease inventory waste (Gross and McInnis, 2003, Wilson, 2010). The answer is for businesses to order raw materials only when they are required, and for completed items to be delivered directly to the target consumer. Instead of pushing items that the consumer may not desire, the firm may let the consumer pull the product as needed (Womack et al., 2003).

2) Overproduction

Overproduction is the biggest waste since it hides all of the other issues in the organization's operations. One of the lean principles is "pull," which means no one upstream should generate an item or service unless the consumer downstream requests it (Womack et al., 2003). As a result, there will be no overproduction. According to (Kilpatrick, 2003), overproduction occurs when a company produces more than the market requires. Manufacturing on a pull system, or manufacturing items when consumers order them, is the equivalent Lean principle. Anything over this (buffer or safety stocks, work-in-process inventories) locks up precious labor and material resources that could otherwise be utilized to meet consumer need. Attempts to prevent long set-up periods; unclear customer demands; poorly applied automation; unbalanced cells or departments; unstable process are all causes of overproduction (Kilpatrick, 2003, Reyner and Fleming, 2004). To avoid overproduction, supply and demand must be balanced. The result of this sort of waste is a lack of cash flow, inflexibility to market demand, and excess inventory, all of which contribute to excessive costs (Stack, 2012). Producing more than is required is a typical practice, as companies want to ensure that they have enough inventory to safeguard their sales. However, this may be hazardous because consumer needs might change, and those inventories may no longer be required. As a result, the items will sit on the shelf for a long period (Wilson, 2010) , slowing the rate of return on investment (Womack et al., 2003). To minimize overproduction, a company must have a clear and well-established method to follow for all processes at all levels, as well as a workflow that adds value to consumers, whether internal or external (Stack, 2012).

3) Non-Value-Added-Processing

First Lean concept is to determine value as it is perceived by our customers. Only the ultimate consumer may determine value, according to (Womack et al., 2003). And it's only useful when it's applied to a certain product., such as a good or service, and often both at the same time, that meets the customer's needs at a specific price at a specific time; otherwise, the company is wasting its time if it's doing something that the customer doesn't explicitly require. Non-value-added may be defined as excessive processing that necessitates extra work but adds no value to the product (or service) from the customer's perspective (Alukal, 2003). Deburring (parts should have been created without bristles), redoing (the product or service should have been done correctly in the first place), with properly designed and maintained tooling), are some of the more common examples of this (Kilpatrick, 2003). Value

Stream Mapping is a methodology that is commonly used to identify non-value-added phases in a process. By tackling the identified bottlenecks and restrictions using VSM, the firm may increase the lead time coming closer to the actual processing time with increased value (Alukal, 2003). So, there are three aspects to consider when determining value for customers' needs: 1) Consumer satisfaction: The firm must offer exactly what the customer want, not a compromise that best matches corporate operations. 2) Price: No one likes to spend more for anything than they have to. So, value is just executing things in the most cost-effective way possible while avoiding waste. 3) Delivery: In certain sectors, being able to minimize lead times may be a genuine order winner. Giving the consumer what they want, when they want it, is what value is all about.

Poor process management and communication, a lack of standards, overdesigned equipment, a misunderstanding of the customer's demands, human mistake, and manufacturing to predict can all lead to non-value-added processing. Those causes can result in negative outcomes such as wasted money, time, effort, and resources, and it is recommended that they be addressed by instituting standard operating procedures, empowering employees, improving documentation, implementing J-I-T processes, and doing everything possible to reduce processes without sacrificing quality (Stack, 2012).

4) Waiting

This comprises awaiting material, information, equipment, machine, tools, personnel, measurement, and information, among other things. All resources must be supplied just-in-time (JIT) according to Lean principles — not too soon, not too late (Alukal, 2003, Kilpatrick, 2003). According to (Stack, 2012), one of the worst aspects of any company is waiting (bottleneck), which occurs when work needs to come to a halt for a variety of reasons, including the next person in line becoming overwhelmed, something breaking down, waiting for approval, or running out of something. Mismatched production rates, extremely long set-up periods, bad shop layout, insufficient workforce, work absenteeism, and poor communications are all possible causes of waiting. There are many ways to deal with this in terms of Efforts to reduce waste; one of its most important there is a need to offer appropriate training to handle workload at obstacles, which some supervisors may aim as a source of financial waste; efforts to push judgment ability to lower levels; and efforts to expand judgment ability to lower levels. Limit this factor by implementing employee cross-training to avoid bottlenecking during interruptions.

5) Waste generated during transportation

Rather to shipping raw materials from a supplier to a collecting facility, processing them, moving them into a storehouse, and then transporting them to the manufacturing process, Lean requires that the product be transported directly from the vendor to the production line location where it will be used. Poor plant/office layout, wasteful or needless handled, and a working process that isn't aligned, and poorly-designed systems, according to Stack, (2012), can all contribute to transportation waste.

As a result, the Lean name for this approach is point-of-use-storage, which is used to eliminate transportation waste (POUS). This method will aid in the reduction of non-value-added operations. It is based on 5s and transparency, as POUS would not function without appropriate housekeeping (Alukal, 2003, Kilpatrick, 2003). Simple actions like streamlining procedures, mending physical layouts, handling items less frequently, and keeping distances between stages as short as feasible can help to solve transportation difficulties (Stack, 2012).

6) Defects

Defects are errors that need more time, effort, and money to correct. (Stack, 2012) In four ways, production flaws and service failures lose resources. The materials are used first. Second, the job that was utilized to create the part (or deliver the service) the starting time around is non-recoverable. Third, labor is needed to modify or replace a product (or redo a service), such as sorting, scrapping, or downgrading. Fourth, labor is needed to deal with any pending consumer complaints (Alukal, 2003, Kilpatrick, 2003). According to the flaws, people are not just upset over the loss of a production unit, but also about the fact that they invested precious time, effort, and energy creating the unit, all of which was lost, not just the production unit. Defects were usually caused by insufficient quality control, repair, and documentation. It can happen when a firm lacks uniformity, resulting in ineffective and missing processes. Defects include inadequate design and inventory management. Particularly when design modifications are made without being recorded, and when client demands are misunderstood. The firm can imagine five scenarios in which errors emerge, according to (Shingo, 1986) :

During the planning stage, first in acceptable standard work processes or stand working procedures. Second, even though the standard procedure is suitable, the real operation exhibits significant variance. Third, raw material parts might be damaged, necessitating examination when such a material is acquired. Fourth, machine friction causes excessive play or causes measuring errors due to worn tools. Fifth, accidental mistakes by employees or equipment that are unexpected and occur at random, making sample inspection difficult.

To reduce errors, the firm can create uniform work plans, tighter quality control at all levels, a thorough grasp of task requirements and client demands, and easy task aids like checklists (Stack, 2012).

7) Excessive Movement

Excessive motion is commonly disregarded as a waste, such as operators and mechanics wandering about seeking for equipment or materials. The folks appear to be lively; they are moving and appear to be occupied. The question isn't whether they're moving; it's whether they're bringing value. Workplace and workstation design are important considerations (Alukal, 2003, Kilpatrick, 2003, Wilson, 2010). Bad workflow, poor layout, cleanliness, and irregular or undocumented work procedures all contribute to excessive motion. This sort of waste movement is also identified using Value Stream Mapping. Having to move around a lot is exhausting may drastically slow things down (Alukal, 2003, Kilpatrick, 2003). Poor workstation/shop architecture, poor cleanliness, shared tools and equipment, workstation congestion, isolated activities, lack of standards, and poor process design and controls are all common causes of excessive motion, according to Stack (2012).

The answer, in essence, is to tie things up so that everything can be readily discovered and put into action whenever it's needed. Reduce the range among stations, and make it as short as possible simpler to reach frequently used items by rearranging the office or store layout. Ensure that all tools and parts are readily available, and that your staff have access to additional printers, copiers, and fax machines. Standardize all folders, drawers, and cabinets, and ensure that everything is kept organized so that anybody can find a file in less than a few seconds. Finally, make certain that the work space is kept tidy.

8) People that are underutilized

Non-Lean settings simply detect underutilization of physical qualities, but Lean settings identify cognitive, creative, and athletic abilities and talents are underutilized. Poor workflow, corporate culture, insufficient recruiting procedures, inadequate or non-relevant training, and excessive staff turnover are some of the most prevalent causes of waste. Employee disengagement has a negative impact on an organization's productivity(Alukal, 2003, Kilpatrick, 2003). The original Japanese enumeration of the seven wastes did not contain this, but it is an important element of the American idea of downtime, according to Stack (2012). Within sense that individuals have been plugged into the system that squandering existing skills, ideas, skills, and skill sets is a waste of time. Lack of collaboration, lack of training, poor communications, management's unwillingness to engage staff in problem-solving, narrowly defined tasks and expectations, and poor management in general can all contribute to this sort of waste. If these wastes are not eliminated, the company's capacity to tap into its people resources would be hampered, making it impossible to successfully address the other seven wastes.

Tables 6 Five lean principles

Lean Principles	Definition
Value	Only the final client can justify it, and it's only relevant when stated in the point of a particular product (a item or a service, and frequently both at the same time) that fulfills the client's demands at a certain product at a certain time. p16 (Womack et al., 2003).
Value stream	The selection of all the concrete behaviors intended to maintain a specific product (whether a good, a service, or, increasingly, a

	combination of the two) via any corporation's three critical business functions: the major issue task, which runs from idea to comprehensive design and development to production launch, and the data management job, which operates from order-taking to detailed scrubbing P19. (Womack et al., 2003).
Flow	“Completion in stages of activities inside the value stream such that a product moves without stoppages, scrap, or backflows from concept to completion, order to delivery, and manufactured goods into the hands of consumers” p.309 (Womack et al., 2003)
Pull	“There should be no one upstream provide a good or service unless a downstream client requests it.” p.67 (Womack et al., 2003)
Perfection	“Regardless of how many times personnel modified a specific task to make it leaner, They might even rely on them discover additional methods to eliminate muda (waste) by decreasing effort, time, space, and errors” p.90 (Womack et al., 2003).

1) The first rule is to specify a value

Value is a crucial starting point for lean manufacturing. It was made by the producer. This is why producers exist in the eyes of the client. p.16 (Womack et al., 2003). To make the value in questions format easier to understand, it may be identified as follows: What do customers expect from you? When do they want it What do they want, and how do they want it? What are the characteristics, capabilities, availability, and price of the product? combination would they prefer? (Fernando and Cadavid, 2007). Customers are either internal, and therefore waiting for the next step, or external, and therefore waiting to pay for the product, thus in order to define value appropriately, the organization must be completely aware of their demand and requirements (Morgan and Liker, 2006). As a result, the first stage in lean manufacturing is to correctly identify value. This may be accomplished by ignoring current assets and technology and rethinking companies on the basis of a robust product line, committed manufacturing members. This necessitates changing the role of a firm's technical specialists as well as reconsidering where value is created in the world. It is Muda (waste) to provide the incorrect item or service in the correct manner (Womack et al., 2003). As a result, if you don't focus on what provides value to your consumers, you're likely to fail at the following stage, "identifying of the value stream."

2) The second premise is to determine the value stream

The next step in lean manufacturing is to classify the value stream, which is a operation that few companies have tried but that nearly invariably reveals significant, if not astonishing, quantities of Muda (waste). From beginning to conclusion, a Value Stream is the collection of processes and activities necessary to get a product to the consumer. The Value Stream is not constrained by company boundaries, which is why it is important to include vendors, factories, suppliers, and even retailers in efforts to identify and evaluate the Value Stream. There are three types of activities: a) those that add value; b) those that do not contribute value but must be avoided at this time; and c) individuals who don't provide any value and should be eliminated (Fernando and Cadavid, 2007). To accomplish this, lean manufacturing must examine the complete set of actions involved in developing and manufacturing a certain product, from concept to design process to actual available, from the initial sale through order entry and capacity planning to distribution, and from raw materials to finished products (Womack et al., 2003). As a result, this phase is critical since the company will be able to view the entire process from beginning to end, making it visible to non-value-added tasks that must be eliminated.

3) The third concept is to create a flow

After the firm has established a precise value, the value stream for a certain product has been thoroughly mapped, and unnecessary procedures have been clearly removed, this phase happens (Womack et al., 2003). The most basic issue is that flow thinking is paradoxical; most individuals assume that work should be arranged in batches by departments. In fact, businesses should strive to make value flow constantly rather than in batches. The concept "one-piece flow" has a lot of charm and is greatly sought for in this paradigm. Furthermore, because typical companies that are efficient do not allow for continuous flow, a focused team approach (closer to the product) is advised (Fernando and Cadavid, 2007). To make continuous-flow process to run for more than a minute or two at a time, every equipment and every worker have to be totally "capable," according to Womack & Jones, 2003. The must constantly be in good working order in order to operate precisely when required, and every part made must be perfect. This means that the production crew must be variety skills in all tasks and that the machinery must be made 100 percent available and accurate using Total Productive Maintenance approaches (TPM). There must be a system in place that includes standardized work. As a result, when the value stream runs smoothly, the business may bring flow into any activity. However, the firm merely serves to expedite the flow of undesirable items, resulting in waste. How can we assure that we are offering the products and services that our consumers truly desire? Responding to customer pull is the next step in understanding how to bring all the elements of a value stream together.

4) Respond to consumer pull as a fourth principle

According to them (Fernando and Cadavid, 2007) Customer Pull: A principle popularized by JIT concepts, according to which Customers should be able to pull "value" (products or services), and the entire manufacturing chain (including suppliers) should be linked in this way that materials are not released and operations are not finished until they are required. Kanban, whether they be real or digital devices that convey the demand for components and subassemblies from one point in the process to the next, are used to develop and enforce the pull discipline. In its most basic form, pull says that no one upstream should create an item or provide a service until a downstream customer wants it.; however, putting this concept into reality is a little more difficult. Starting with a real consumer expressing a need for a real product and working backwards through all the processes necessary to get the desired product to the consumer is the best approach to comprehend the logic and challenge of pull thinking (Womack et al., 2003). As a result, putting in place a pull system will reduce inventory levels and allow the company to know exactly what its consumers are ready to pay for. The firm may utilize the pull mechanism to locate and eliminate waste after establishing flow.

5) The fifth principle is to strive towards excellence

Perfection is the fifth and final concept of lean manufacturing, and it is the reason why the need to examine the four initial principles interact in a virtuous loop. Continuous Improvement: As the Toyota luxury brand (Lexus) ad tagline puts it, it is "the ardent pursuit of excellence." It's the belief that improvement efforts never end, and it's the determination to maintain the improvement discipline in place (kaizen).

2.7 Practices of lean manufacturing

LM provides the organization with a collection of tools and procedures that may be utilized to assist the company accomplish its goals. Many tools or Lean Building Blocks are used by Lean practitioners to minimize or eliminate the above wastes. Although Lean's building blocks are tactical and narrowly focused, they are most successful when utilized collectively and used cross-functionally throughout the system (Kilpatrick, 2003). The most prevalent problem is that businesses lack the necessary core work pieces to launch a Lean program. More significantly, organizations must understand this and believe that, regardless of the present condition of the process, a Lean effort can be launched and methods like kanban deployed quickly. They must, for example, have a relatively consistent materials supply and excellent machine availability, to mention a few requirements. Most essential, they must have a process in place that already produces at a high degree of quality; procedures that demonstrate both process and product quality (Wilson, 2010). According to (Goh and Richards, 1997), the effectiveness of any management practice adoption is frequently determined by company characteristics, and not all companies can or should use the same set of practices or approaches. Organizational contexts, for example, have been conspicuously absent from studies on the adoption of JIT and TQM programs or other lean manufacturing methods (Shah and Ward, 2003). Successful practitioners realize that, while the majority of them may be implemented as stand-alone programs, only a small percentage of them have a substantial impact when utilized alone. Furthermore, the order in which things are implemented has an influence on the total impact, and doing things out of order might backfire (for example, you should handle rapid changeover and quality before lowering batch sizes) (Kilpatrick, 2003). Which approaches make up your Lean manufacturing system, according to (Wilson, 2010)? During the conceptual stage of the strategy discussion, tactics are often mentioned in a small group activity as being necessary to achieve the strategies, whereas skills are the individual actions that must be done to achieve the tactics. To implement kanban, for example, a range of abilities are required, including the ability to create kanbans, size kanban volumes, arrange kanban circulation, and so on. As a result, the recommendation is to fully assess one's own demands and pick one's own approaches. Henry Ford was the first to integrate a complete manufacturing process in the early 1900s. Ford created flow manufacturing by combining reliably replaceable parts with standard work and moving conveyance. Ford's method was improved by Kiichiro Toyoda and Tai'chi Ohno (Ohno, 1988). Difficult financial conditions at Toyota prompted these two to expand on Ford's notions in order to pioneer the widely recognized seven lean principles for waste elimination, as stated in the following. 1) Eliminate waste from overproduction, 2) Eliminate waste from waiting, 3) Eliminate waste from transportation, 4) Eliminate waste from processing itself, 5) Eliminate waste from stock on hand (inventory), 6) Eliminate waste from movement, and 7) Eliminate waste from producing faulty items.

According to Kiichiro Toyoda's seven wastes and Tai'chi Ohno's idea, non-Lean settings primarily detect underutilization of physical characteristics, but Lean settings identify underutilization of mental, creative, and physical talents and talents. The original Japanese enumeration of the seven wastes did not contain this, but it is an important element of the American idea of downtime, according to Stack (2012). If these wastes are not eliminated, the company's capacity to tap into its people resources would be hampered, making it impossible to successfully address the other seven wastes.

2.8 Overview of firm sustainability

The relevance of the sustainability movement has grown as a result of global factors such as the energy crisis, recession, and climate catastrophes. Sustainability encapsulates the promise of social progress toward a more fair and prosperous society where the natural habitat and cultural achievements are valued are protected for future generations (Dyllick & Hockerts, 2002). For most of the last 150 years, the world's demand for business development and social equality has been a key concern.

Furthermore, with another worry about the natural systems' carrying capacity, the present primary issues confronting humankind become entwined. The idea of sustainable development gained its first major international acknowledgment in 1972 at the United Nations Conference on the Human Environment in Stockholm, according to the Sustainable Development Commission UK (2011). Despite the fact that the phrase was not expressly used, the world community agreed on the concept. While much has been done on all three issues over the last four decades, the 1992 Earth Summit in Rio de Janeiro was a watershed moment, The United Nations Conference on Environment and Development, where the concept of sustainable development served as the foundation, was the first worldwide effort to expand action plans for moving into a more sustainable pattern of development; which was also the first worldwide attempt to develop action plans and strategies for moving towards a more sustainable level of urban; It was also the first worldwide attempt to draft action plans and strategies for advancing towards the Millennium Development Goals (Keating, Future, & Eng, 1993). Stakeholders are increasingly requesting or expecting businesses to be more environmentally responsible in their goods and operations for a variety of reasons, including legal obligations, product stewardship, public perception, and possible competitive benefits (Rusinko, 2007). The topic of sustainability has developed as a new management function that must be integrated into business school curricula, and the organization's position in relation to the natural environment has prompted a renewed realization of our common need for a sustainable focus, with its origins in environmental management (Young & Dhanda, 2012).

Sustainable manufacturing procedures are one of the most important environmental steps taken by the manufacturing industry to protect improve the environment and people's quality of life while deploying troops, from a global viewpoint to the business sector (Salwa Hanim Abdul-Rashid, Novita Sakundarini, Raja Ariffin Raja Ghazilla, & Ramayah Thurasamy, 2017). Value of economic is no longer the sole criterion for evaluating industrial success. The influence of manufacturing operations on environmental and social elements should be taken into consideration as the foundation for measuring factory outcome, which is referred to as sustainability performance, in the context of sustainability. A sustainable business contributes to long-term development by offering economic, social, and environmental benefits, or what is referred to as "the triple bottom line" (Elkington, 1998). The “triple bottom line” concept asserts that a company's ultimate success or health may and should be determined not only by its profit and loss bottom line, but also by its social/ethical and environmental performance (Norman & MacDonald, 2004)

Green is a synonym meaning sustainable. The term "green" typically connotes a preference for the natural over the man-made (Young & Dhanda, 2012). If a company wants to improve its social and environmental responsibilities, it may implement and integrate Lean and Green methods. The ideas of Lean Manufacturing and Green Management intersect in one of the most important areas of waste reduction approaches. Manufacturers may use both Lean and Green methods at the same time to develop an environmental position that leads to lower costs and risks, higher income, and a better brand image (Fercoq et al., 2016).

As a result, Toyota was the first business in the global automobile sector to achieve “zero waste to landfill” (Farish, 2009) . Identify the link between Green operations and Lean outcomes, according to (Bergmiller and McCright, 2009). They discovered that Lean firms who use Green practices have greater results than those that don't. Lean is not just a catalyst, but it also works in tandem with the Green approach. This indicates that Lean is beneficial to Green practices, and Green practices, in turn, have a favorable impact on current business practices (Dües, Tan, & Lim, 2013). As a result, lean and green are linked at the strategic, tactical, and operational levels (Fercoq et al., 2016).

2.9 The advantages of a sustainability policy

Sustainability has evolved into more than a fad or a buzzword during the last two decades. According to studies (McIntyre, 2016), when sustainability is thoughtfully integrated into corporate processes, it offers significant commercial benefits. The following are the ten measures that organizations may take to become more sustainable, according to (Staff, 2007) : a) Integrate sustainability innovation into a company's entire strategy. c) Develop a plan that prioritizes sustainability. c)

Incorporate sustainability into every aspect of your company. d) Focus on deeds rather than words. e) Establish strong board-level governance to ensure that sustainability is a priority. f) Establish strict guidelines f) Engage stakeholders to get them on board. h) Harness the power of people via recruiting, staffing, training, and incentives. I Join sustainability-focused networks. j) Go beyond reporting and integrate all business systems with the company's long-term sustainability goals.

When considering whether or not to become a sustainability-practicing business, the firm should consider the following six key benefits:

2.9.1 Brand image is improved, and you have a competitive edge

According to the Natural Marketing Institute (McIntyre, 2016), which surveyed over 53,000 U.S. customers, 58 percent of customers evaluate a company's environmental effect when deciding where to buy products and services, and are more inclined to buy from firms that follow sustainable practices. This equates to a customer base of 68 million Americans who are more likely to patronize businesses that have a strong track record in terms of personal, social, and environmental values. Consumers also prefer firms who actively assist According to the Cause Marketing Forum, benefits arise through doing good in their neighborhoods.

As seen by Colgate's public awareness advertisements during the Super Bowl encouraging water conservation, improving brand recognition by "doing good" is becoming one of the foundations of advertising campaigns. People have lived for millennia without electricity or paper, but mankind cannot exist without water, especially drinkable water. Encouragement and practice of not only does resource conservation enhance brand recognition, but it also goes out to employees, their families, and others. The opportunity to improve brand image is lost if the company does not practice what it preaches. (McIntyre, 2016)

Businesses have already recognized the value of sustainability. It benefits the environment as well as the financial line and brand recognition. The Subaru of Indiana Automotive facility, which accomplished its aim of being the nation's first zero-landfill vehicle manufacturing, was highlighted in a recent Bloomberg Businessweek story. The factory's garbage is recycled 98% of the time, and the rest is burned at a waste-to-energy facility. Last year, this intense focus on waste minimization saved the firm $5.3 million, according to a plant executive. Employees have benefited from this approach as well. The factory has never had a layoff and offers an impressive package of perks to its employees (Brown, 2011; Willard, 2012).

2.9.2 Increase productivity, lower expenses, and boost profits

Attempt to avoid that sustainable business practices reduce corporate profits. Sustainable business strategies provide more efficient operations that reduce effort and preserve resources, resulting in higher employee losses and reduced costs. (McIntyre, 2016). Businesses that focus on sustainability, according to (Young & Dhanda, 2012), can be more innovative and profitable. According to a research by BT and Cisco, sustainability may lead to economic success and allow companies to develop new goods and services. Stakeholders are interested in learning more about what firms are doing to better the world and reduce their impact. Profit is still essential, but it is not the only factor used to assess firms. Energy saving tactics range from simple measures like turning off lights that aren't in use and insulate walls to more complex measures like installing subsurface heating and cooling systems to save money. The cost of implementing projects with a greater overall impact will almost probably be higher, but the long-term advantages will be worth it (McIntyre, 2016).

2.9.3 Boost your company's capacity to comply with regulations

According to (Denton, 2002), the discussion has shifted from an initial commitment to greenhouse gas mitigation to attempting to persuade obstinate countries like the United States to sign on to the Kyoto Protocol and ratify it. Northern objectives and interests are reflected in climate change discussions such as those leading to the Kyoto Protocol. Issues affecting individuals living in poverty, such as how they might adapt to global warming, have been sidelined or overlooked. The majority of LDCs believe that their needs for adaptation methods have not been addressed or that they have not gotten enough attention. As a result of all the talk about climate change, energy scarcity, and environmental damage, it's no wonder that state and federal government agencies are implementing environmental rules.

Integrating sustainability into a company's operations will enable it to respond quickly to changing requirements. As a result, the company's likelihood of adhering to national regulations will be high.

2.9.4 Attract employees and investors to your company

People, especially younger population reared on a continuous diet of environmental preservation messaging, prefer to be identified with the good. They don't want to be associated with firms that have been tied to natural disasters and social well-being issues. Show that your firm cares about the environment and its employees, and you'll attract the kind of individuals you want to hire as well as the finances you need to grow. According to the Food store Manufacturers Association/Food Products Association (GMA/FPA), integrating sustainable supply chain methods will benefit the sector by increasing profit, assisting the industry in working with federal agencies to draft legislation, and increasing customer loyalty, all of which would attract investors, according to (Staff, 2007).

2.9.5 Reduce waste

This is perhaps the most straightforward and obvious approach to engage in long-term behavior The program began in the 1990s with offices collect empty bottles for recycling and has since grown to include waste reduction in paper (tree and forest habitat conservation), moving out lightbulbs for LED lights, as well as value engineering items (reworking or establishing new processes that utilize less raw materials and waste less material in the manufacture of goods) (greater efficiency combined with fewer bulbs used). The objective of Sonoco Sustainability Solutions (S3) is to decrease trash entering landfills. Sonoco intends to create waste-reduction initiatives for its clients. Sonoco Sustainability Solutions (S3) has set a target to decrease the amount of trash that ends up in landfills. Sonoco intends to create client programs to help them minimize the amount of waste they generate. S3 will create new methods for generating income from trash. This initiative can help Sonoco's manufacturing clients save money by reducing waste and repurposing it.

2.9.6 Boost investor confidence

Not only can sustainability improve profitability, but it can also help you earn more. McKinsey conducted research on 40 firms in 2014 for their study " Earnings with a Reason: How Sustainability Organizing Can Help the Bottom Line," in which they sought practical solutions "to extract value from sustainability". According to them, a study conducted by Deutsche Bank found that firms with strong environmental, social, and governance ratings outperformed the market in the medium and long run. The Carbon Disclosure Project's research had comparable outcomes, according to McKinsey. Calculations of share prices back up these claims: “A $1 investment in a real worth portfolio of high-sustainability enterprises in 1993 would have grown to $22.60 by the end of 2010, compared to $15.40 for a portfolio of low-sustainability enterprises.” (McIntyre, 2016). The Principles for Responsible Investment (PRI) agreement has been signed by nearly signatories include one thousand two hundred institutional investors from all over the world, with the purpose of better understanding the consequences of business sustainability and aiding signatories in implementing ESG problems into their investment decision-making and ownership processes. (UNEP,2013). When it comes to sustainability, the old adage "anything simple isn't worth doing" holds true. To get on board the sustainability bandwagon and make it a success, it needs passion, commitment, and follow-through from the top down. However, if your company is capable of doing so, even when sales decline, morale and productivity will rise and expenses fall. It's the ideal win-win situation for stockholders, customers, and employees alike (McIntyre, 2016).

2.10 Definition of sustainability

Sustainability is a fluid notion, making it difficult to pin down. In principle, sustainability is defined as "filling current demands without jeopardizing future generations' ability to satisfy their own needs." (Tavanti,2010). The Earth's natural resources must be utilized at a rate that allows for renewal in order to live sustainably. Our consumerist civilization, on the other hand, has put immense strain on the planet (Richardson et al., 2009). Many of today's environmental issues, such as global warming, pollution, natural resource depletion, and biodiversity loss, have been exacerbated by current production and consumption practices (Raskin et al., 2010). Although there are over 500 definitions of sustainability, the phrase often refers to the ability to survive. In ecology, "biological systems stay varied and productive throughout time" is described as "sustainability." For people, it's the "potential for long-term maintenance of well-being, which is dependent on the preservation of the natural environment and natural resources"(Bromley, 2008), and the majority of them are related to a certain subject or sector, such as sustainable community or sustainable design. Regardless of the many definitions of sustainability, the essential precepts are as follows: Living on Earth has environmental constraints., Humans are responsible for avoiding and removing pollution. The economy, environment, and society are all interrelated and interdependent (Tavanti, 2014).

Sustainability is founded on a basic premise, according to the United States Environmental Protection Agency. Everything we needed for our survival and well-being is completely reliant on our natural surroundings. In order to achieve sustainability, conditions must be created and maintained that allow humans and the environment to coexist in productive harmony for the advantage of coming generations. Nonetheless, the Brundtland Report, published by the World Commission on Environment and Development (WCED), seems to be the most widely acknowledged definition of sustainability in the field of sustainable development. “Sustainable development” is described as “development that meets present demands without risking the ability of future generations to meet their own needs.” (WCED, 1987).

2.10.1 Sustainability Production

These non-sustainable consumption and production methods are having an increasingly negative impact on the environment, society, the economy, and businesses. It is undeniable that our quality of life, prosperity, and economic development are all reliant on our capacity to live within the constraints of resource availability. People and families should participate in change, but it is primarily the duty of businesses, government, and the international community(Pinto-Ferreira et al., 2015). Sustainable production is a subset of the broader idea of sustainable development, which originated in the early 1980s (Leahu-Aluas, 2010) in reaction to heightened knowledge and concern about the environmental effects of economic growth and globalization of business and commerce. Sustainable development, according to (Richardson et al., 2009) , is improvement that meets current needs without risking future generations' ability to meet their own (Gimenez et al., 2012, Rosen and Kishawy, 2012). There are several definitions of sustainable manufacturing that must be studied and contrasted.

Tables 7 Sustainable Production Definitions

References	Definition
Department of Trade for the USA	Manufacturing goods that have a low negative environmental effect, save energy and natural resources, are safe for workers, communities, and customers, and are commercially viable. (Leahu-Aluas, 2010).
The Lowell Centre for Sustainable Production (LCSP)	The creation of products and services using methods and process that are (Richardson et al., 2009): x Non-polluting x Able to save energy and natural resources x Economically feasible x Workplaces, communities, and customers are all safe and healthy. All workers should be social and creative.
The Institute of Manufacture, University of Cambridge	Sustainable production is defined as the development of technologies that convert resources without emitting greenhouse gases, utilizing non-renewable or hazardous resources, or leaving waste leftovers (O'Brien, 1999).
Sustainable Manufacturing Consulting, Indianapolis	A commercial activity in the industrial sector that encompasses all of a company's processes and decisions in the context of the social and natural environment in which it functions and influences with the stated objective of reducing and eliminating any undesirable consequences while keeping the intended level of technological and economic performance. (Richardson et al., 2009).

In order to solve this issue, Sustainable Manufacture (SM) or Sustainable Production arises, which examines three dimensional perspectives: the environment, society, and economics (Rosen and Kishawy, 2012, Visser et al., Giddings et al., 2002). As a result of this viewpoint, the TLB, or Triple Bottom Line, was developed (Foran et al., 2005, Brown et al., 2006) to ensure that a company moves forward with a triple goal in mind, namely, to respond to the needs of various interest groups by creating a "Triple result account," Outcomes from the economic, social, and environmental realms will be included.

2.11 Triple Bottom Line (TBL)

Business consultant In the 1990s, John Elkington, the creator of SustainAbility, used the phrase "triple bottom line" to describe the economic, environmental, and social benefits of investment that occur outside of a company's economic dimension (Elkington, 2004). Companies should prepare three alternative bottom lines, according to his reasoning. The first is the "bottom line" of the profit and loss statement, which is the traditional metric of business earnings. The next is the bottom line of a company's "people account"—a measure of how socially responsible a company has been in some form or another across its operations. The company's "planet" account's bottom line—a measure of how ecologically responsible it has been—is the third. (http://www.economist.com, 2009). The 3Ps (people, planet, profit), triple value addition (Roberts & Cohen, 2002), and blended value are terms used to describe this (Emerson, 2003). The business's obligation, according to (Hammer and Pivo, 2016), extends to all of its stakeholders, not just its shareholders. To put it another way, it considers the business's influence on social and environmental ideals as well as financial rewards. Whereas conventional business models focused on earning money and profit, TBL accounting understands that without happy workers and a clean environment, a company is bound to fail in the long term. It has gained momentum in sectors such as business, planning, finance, and real estate that are connected to economic growth (Hammer and Pivo, 2016).

TBL encapsulates the essence of sustainability by assessing the global impact of an organization's performance., according to (Savitz & Weber, 2006). A positive TBL indicates that the company's worth has increased, encompassing earnings and shareholder value, as well as social, human, and environmental capital. TBL is now used as a type of balanced scorecard that measures how well a firm creates value for its shareholders and society in terms of numbers and language. There are numerous standard measuring parameters to consider:

2.11.1 Economic (Profit)

The income statement account's "bottom line" is the basic metric of business earnings. Profits are crucial for all enterprises, whether they are in the public or private sector. According to (Savitz & Weber, 2006), the balanced scorecard captures in numbers sales, profit, ROI, taxes paid, monetary flow, and employment generated under profit result performance.

It's more important to make an honest profit than to make a profit at any expense. It must be constructed in accordance with the other two principles of the environment (planet) and social justice (People). The profit element is the true economic value generated by the firm after all costs have been deducted.

2.11.2 Environmental (Planet)

Natural capital is a term that describes a company's environmental policies. A company will try to reduce its environmental effect in all aspects of its operations, from raw material procurement to manufacturing processes to shipping and administration. Furthermore, TBL will not be involved in the manufacture of hazardous materials. According to (Savitz & Weber, 2006), the balanced scorecard captures in numbers air quality, water quality, energy use, and waste created under environmental outcome performance.

Dr. Robin Kent, a waste management expert, claims that trash is costing businesses actual money that is being deducted from their earnings. The firm considers trash reduction and waste recycling as ways to reduce the production's environmental effect. (Marr, 2012)

2.11.3 Social (People)

In its most basic form, it entails treating your employees with respect. This is also linked to human capital, and it refers to a company's fair and helpful business decisions toward its employees as well as the community and region in which it operates. According to (Savitz & Weber, 2006), the balanced scorecard captures in numbers labor practices, community impacts, human rights, and product responsibility under social outcome performance.

2.12 Sustainability objectives and activities

In fact, OM sustainability has been improved thanks to the discovery of variety of drivers. Internal (cost reduction by waste reduction) and external (cost reduction via waste reduction) drivers, for example, have been identified (government or customer pressure to improve sustainability performance). What "sustainable" implies, however, is considerably less clear (Wagner, 2008) et al, p. 125). While most definitions of "sustainability" focus on environmental problems, a wide variety of challenges that are important outside the natural environment have been highlighted. Piercy and Brammer (2012) established six aspects after conducting a meta-analysis of several hundred prior studies in the field (environmental, workforce, supply chain, community, governance and quality issues).

2.12.1 The environment

This topic concerned the impact of business operations on the natural environment, including pollution and emissions from manufacturing and the materials used in products, energy use, transportation emissions, the use of recycled materials in manufacturing, and post-consumer product recycling (see, for example, Buysse and Verbeke, 2003; Székelly and Knirsch, 2005; Jenkins, 2006; Maloni and Brow, 2007). Lean production has previously been linked to a number of environmental benefits (see above). The basic idea is that generating the same amount of output with less resources (materials, energy, and capital) is fundamentally good for the environment while simultaneously lowering the company's operating costs (Florida, 1996). Similarly, improving quality (a fundamental lean goal) reduces manufacturing errors and the resulting scrap/rework, lowering costs and decreasing environmental impact (Simpsonand Power, 2005).

2.12.2 Workforce issues

This has to do with how a company handles its employees. Workplace operational concerns (providing a safe workplace environment with appropriate working conditions), pay (fair salaries and payments), diverse concerns (nondiscrimination in hiring), and union relations are all issues that need to be addressed (recognition) were recognized as the four sub-dimensions (see: Panapanaan et al., 2003; Meijer and Schuyt, 2005; Wagner et al., 2008). Workers' engagement/involvement and environmental performance have previously been linked in studies (Florida, 1996; Kitazawa and Sarkis, 2000; Sroufe, 2003). Lean operations and sustainability both strive for better working conditions. A change toward an engaged, motivated, and well-trained workforce underpins workplace advances in lean improvement. (Storey, 1994). As a result of visible management, worker training, and standardised work, lean operations tend to provide greater levels of safety (Taubitz, 2010). In addition, incentive payments and a typically higher level of compensation have been found in lean vs non-lean operations (Womack et al., 1990; MacDuffie, 1995). These elements, which are all expressly lean, help to clearly build a long-term working environment.

2.12.3 Supply chain

It is about how an organization monitors and responds to the actions of sixth organizations that are not under their control. This covered labor practices (civil liberties, such as the avoidance of child labour or sexual slavery), supplier treatment (on-time payment and transparent and honest transactions), and fair trade/ethical sourcing problems (positive conduct to assist suppliers) (see: Carter et al., 1999; Maloni and Brown, 2006). For the objectives of cost reduction and quality improvement, the lean supply chain approach focuses on developing tight, long-term partnerships with suppliers with high levels of information transparency (Lamming, 1993). Close supplier connections are increasingly being shown to boost environmental performance (Klassen, 2001 It has been found that sharing information to decrease the bullwhip effect reduces wasteful manufacturing, shipping, and stock holding, lowering a variety of environmental consequences (Kainuma and Tawara, 2006). Close ties also boost inter-firm innovation, which helps to minimize the supply chain's overall environmental effect (Frosch, 1994; Florida, 1996; Geffen and

Rothenberg, 2000; Simpson and Power, 2005). A number of governance, ethical, and workforce concerns are also element of the supplier evaluation audit engagement in a lean approach, requiring a supply partner to operate in compliance with a variety of sustainability goals (Nishiguichi, 1994).

2.12.4 Community contributions

This was a connection to the company's beneficial impact on the community in which it worked, such as charitable gifts and favorable social support (see: Lee and Shin, 2010). Maintaining a positive reputation in the local community is an explicit component of the lean organization's strategy-setting process. While sometimes neglected, this issue has proved critical to a variety of lean businesses (Womack and Jones, 2005). For example, since the 1950s, Toyota has placed a strong emphasis on community concerns, particularly those affecting present and past Toyota locations and employees. These aren't merely declarations of philosophy; they're also linked to specific performance measures (Toyota, 2011).

2.12.5 Governance and ethics

This was about business activity management, such as socially responsible investing, public disclosure of actions, having a clear and documented ethical policy, and guaranteeing legal compliance (see: Maignan and Ferrell, 2000; Kok et al., 2001; Turker, 2009). These challenges of sustainability are based on information transparency both inside and between firms. In every lean organization, the change toward openness is also critical (Lamming, 1993). A lean organization has standardized work patterns and clear communication routes between workers, suppliers, and consumers (Womack et al., 1990). This openness aids internal governance processes while also decreasing wastage at the firm's perimeter, as just the resources required are brought in, avoiding the bullwhip effect (Corbett and Klassen, 2006; Kainuma and Tawara, 2006).

2.12.6 Product and service quality

This included ensuring that items were safe and suitable for purpose, as well as that marketing activities were truthful (see: Graafland et al., 2004; Anselmsson and

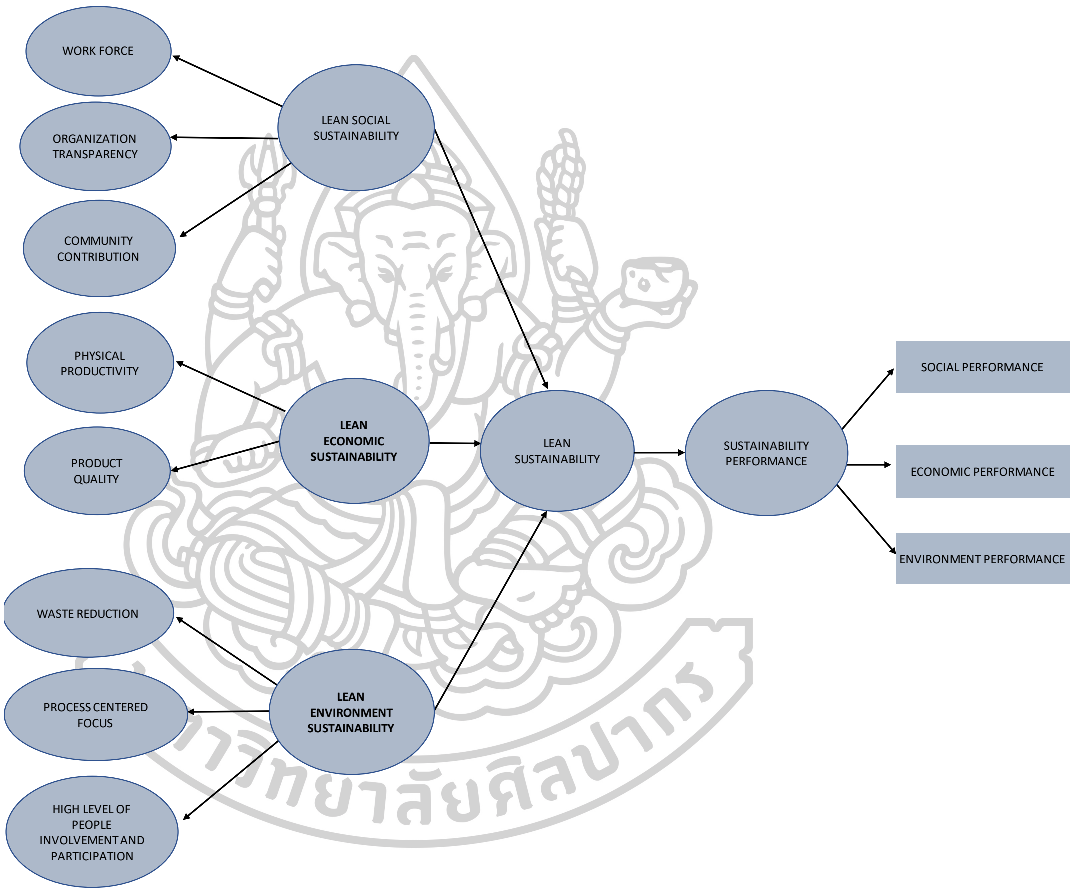
Johansson, 2007; Turker, 2009). Improving product quality is arguably the area where sustainability and industrial operations intersect most clearly. One of the main goals of lean operations is to improve product quality (Womack et al., 1990). Furthermore, open and honest contact with consumers is crucial (Womack and Jones, 2005).

2.13 Sustainability and Lean Manufacturing

According to (Womack and Jones, 1997), lean manufacturing is a business model that focuses on eliminating non-value-adding operations in order to provide higher value to consumers. The 'lean' idea originated on the shop floors of Toyota Motor Corporation in Japan, which focused on reducing waste in operations (Herron and Hicks, 2008, Ohno, 1988). The authors of the famous book The Machine That Changed the World (Womack et al., 1990) created the terms "lean manufacturing" and "lean production," and boosted the lean movement's momentum. As the notion grew in popularity, people became more interested in the role of lean manufacturing processes in attaining long-term sustainability goals (Fliedner and Majeske, 2010, Garza-Reyes, 2015). Increasing demands from the last decade, the government, regulatory authorities, and society have pushed businesses to match their activities with environmental sustainability principles.

The literature on how lean manufacturing may contribute to sustainability outcomes and transition operations to lean sustainability business practices is still lacking in this study. Without requiring particular sustainability action, considering the areas of implementation will help manufacturing businesses to divert their attention to possible areas for enhancing their sustainability performance. Conversely, many of the study has been focused on examining certain lean manufacturing and practices in standalone, such as lean management, which removes waste along the whole value stream of a product (Shah and Ward, 2003), JIT waste minimization (Wang and Taj, 2005), and capacity utilization maximization (Treville and Antonakis, 2006).

In this setting, the study's purpose was to look at the link between lean manufacturing and long-term sustainability. The literature on lean management and sustainability focused on the three major components of sustainability (environmental, ecological, and social). (Both financial and social). This concept identifies three essential dimensions or parts of sustainability: economic, environmental, and social issues in a "triple bottom line" approach (Dyllick and Hockerts, 2002). As a result, this study will begin with environmental, social, and economic results in order to address all aspects of sustainability in various functional areas. (See figure 1)



Figures 1 Lean Sustainability towards sustainability performance Conceptual Framework

2.14 Environmental Sustainability and Lean Manufacturing

The objective of this study is to look into the impact of lean environmental sustainability practices based on lean and environmental principles in several functional areas of automobile manufacturing companies on sustainability performance. The explanation begins with a number of research that have discovered a direct positive relationship in various aspects, and then groups the data together to show that applying a variety of LM practices and tools has a direct good influence on environmental outcomes. The area of sustainability began as a new business discipline that had to be included in the business school curriculum, and then the position of the organization in relation to the natural world generated a fresh understanding of the need for a sustainability emphasis (Young and Dhanda, 2012). In terms of business, they have some environmental impact, which might range from lighting office buildings to, more importantly, trash and pollutants created during manufacturing operations (Bansal, 2005). There are several types of pressure that may be used to encourage businesses to decrease their environmental impacts and comply with environmental regulations. Local communities put pressure on businesses to manage their environmental performance results, as do investors, consumers, workers, non-governmental groups, and government legislation. It has been discovered that efficient environmental performance helps to increased internal results in addition to improving environmental performance from external demands on companies (Theyel, 2006, Holt and Ghobadian, 2009). Reduced waste disposal, lower regulatory compliance costs, better efficiency, lower energy and resource costs, lower liability and risk, and improved company reputation are some of the operational results connected with environmental strategy. As a result, it is critical for managers to focus on how to successfully manage environmental performance. (Hart, 1997, Sharma and Vredenburg, 1998, Hart and Ahuja, 1996). According to (Kleindorfer et al., 2005, Pagell and Gobeli, 2009) , when assessing the environmental effect of manufacturing, the primary focus should be on the firm's resource consumption and overall impact, such as pollution or emissions. Reduced solid and liquid wastes, pollution, resource utilization, intake of hazardous, dangerous, and poisonous products, and the number of environmental mishaps, as well as increased compliance with environmental requirements, are examples of good environmental outcomes. (Eltayeb and Zailani, 2009, Geyer and Jackson, 2004, Veleva and Ellenbecker, 2001, Zhu and Sarkis, 2004).

2.14.1. The clear link between Lean and the environment's sustainability

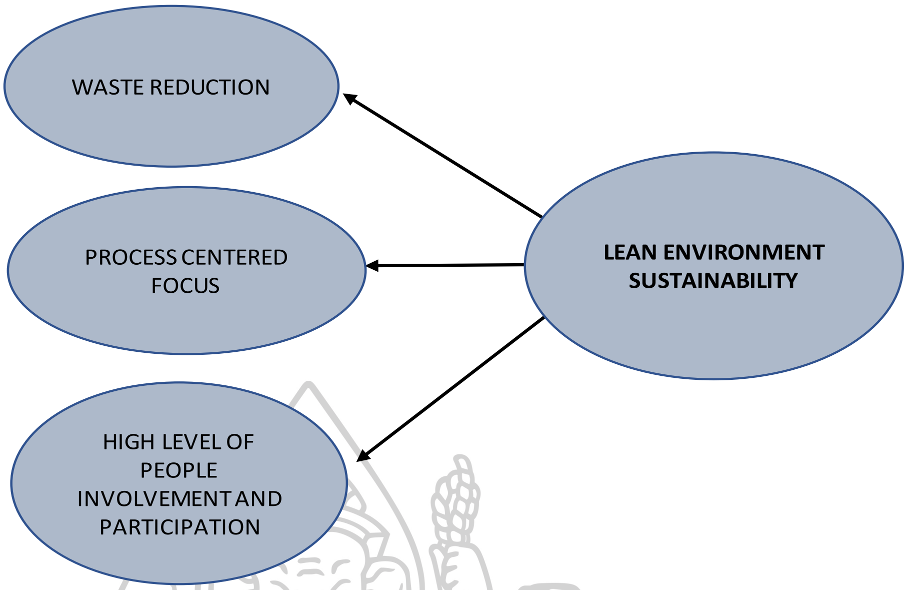
When it comes to the study of lean and green or environmental thinking, they've risen in popularity over the last two decades, impacting resource efficiency techniques. At the end of the day, adopting green design and manufacturing techniques is a no-brainer because they are based on the same fundamental concepts. Previous research has largely focused on lean manufacturing and green manufacturing approaches (Florida, 1996). Many of case studies done by the United States Environmental Protection Agency (EPA) have discovered a plethora of environmental benefits that result from the successful application of LM principles and methods (EPA, 2000, 2003, 2007). Despite the fact that environmental trash is not formally included, in lean wastes, they are entrenched in seven deadly wastes, and lean manufacturing methods can result in significant environmental benefits (EPA, 2003). Together, the lean and green system models offer a systematic and holistic method for turning a firm green, allowing it to be utilized as a possible sustainable business model for achieving the greatest economic and environmental outcomes. (Zokaei et al., 2016).

Adopting lean and green techniques has substantial benefits in terms of raw material reduction, utility footprint reduction, and cost reduction (Sobral et al., 2013, Zokaei et al., 2016). LM works as a catalyst or facilitator for environmental ideas and practices to be adopted (Maxwell et al., 1993). By using less raw materials, LM accidentally improves some environmental outcomes, such as minimizing hazardous chemical dispersion (Moreira et al., 2010, Yang et al., 2011b). According to several recent research, the link between LM and environmental outcomes is mediated by the adoption of environmental behaviors. To overcome the tensions between LM and environmental performance, it is critical to provide resources to green activities. The adoption of environmental management techniques is favorably connected to a previous LM endeavor. (Yang et al., 2011b, Hajmohammad et al., 2013). In truth, many Lean enterprises have been proven to have improved environmental results as a side effect of not having any strategy advice to integrate the notions of LM with the principles of "Green" Manufacturing (Sawhney et al., 2007, Moreira et al., 2010, Taubitz, 2010, Vinodh et al., 2011, Yang et al., 2011b, Simpson and Power, 2005a). Some academics investigate the value of combining LM activities with "green" manufacturing, and suggest approaches or collaborative implementation (Soltero and Waldrip, 2002, Larson and Greenwood, 2004, Taubitz, 2010, Miller, 2010, Vinodh et al., 2011, Aguado et al., 2013). Implementing LM techniques and technologies has been proven to have a direct beneficial relationship between LM and environmental results. The study of (Florida, 1996, Rothenberg et al., 2001) found a positive association, indicating that LM continually increases resource efficiency. According to (King and Lenox, 2001, Larson and Greenwood, 2004), the outcomes of LM's continual resource efficiency improvement include decreases in the usage of materials and energy consumption, which as a result, there is less pollution in the environment. Although some writers have shown that applying a variety of LM practices and tools has a direct positive influence on environmental outcomes, the data are still not definitive, since positive associations have been discovered (Moreira et al., 2010, Yang et al., 2011b). Similarly, JIT achieves certain environmental goals (increased traffic congestion and pollution in cities). Lean firms, on the other hand, implement environmental measures proactively in order to reduce pollution (Cusumano, 1994). As a memory help, a number of acronyms for the Eight Wastes have been offered, but DOWNTIME appears to be the most popular. It's plain, uncomplicated, and suitable. The following is a list of what each letter stands for: 1) Deficiencies. 2) Excessive production. 3) The act of waiting. 4) Talent that isn't being used or is being underused. 5) Getting about. 6) Make an inventory. 7) Movement 8) Over-processing Variations in procedures may be linked to waste. To combat such wastes, statistical methods such as the Six Sigma DMAIC (define, measure, analyze, improve, control) approach may be useful (Stack, 2012). Similarly, some writers adapt a number of Lean manufacturing techniques and tools, such as Kaizen events, 5S, Pokayoke, value stream mapping, and error-proof procedures, for inclusion into environmental principles; this stresses the necessity for LM approaches to be implemented with an environmental focus (Pojasek, 1999, Soltero and Waldrip, 2002, Simons and Mason, 2003, Mason et al., 2008). Despite these mixed findings, many studies conclude that, while LM may clash with environmental performance in some places, particularly when pollution control technologies are necessary, it does not provide substantial possibilities for environmental improvement (Rothenberg et al., 2001, Larson and Greenwood, 2004, Sawhney et al., 2007).

A limited number of studies have recently discovered correlations between the incidence of advanced pollution protection techniques and the adoption of lean manufacturing tactics by businesses. The zero waste and continuous improvement principles of lean are credited in this study for the mutual benefits of lean manufacturing and environmental management practices. Rothenberg (Rothenberg et al., 2001) (King and Lenox, 2001), discovered that firms with lean manufacturing processes had high levels of advanced pollution avoidance. According to Rothenberg (2003), pollution control operations are frequently value-added for businesses because they decrease costs by reducing material usage or avoiding waste management expenditures. The goal of lean is to create an efficient and well-organized system that is committed to continual development and the elimination of all types of waste. The likelihood of a mutually beneficial benefit to firm environmental management practice is high.

2.14.2 Lean Principles and Environmental Concerns

Although there is general agreement that lean can improve a company's environmental performance, authors agree that lean manufacturing has a strong association to waste mitigation and emissions prevention, especially when production processes efficiency and environmental performance are combined. Authors have different ideas about how; however, researchers agree that lean production has a positive correlation to waste mitigation and environmental damage prevention. The research frame of (Martínez-Jurado and Moyano-Fuentes, 2014) refers to the concepts of lean and environmental. The following fundamental ideas govern the Lean and Green or Environmental debate that the research has framed: a) Waste Reduction Principle b) Process Centered-Focus Principle c) Involvement and participation of a large number of individuals (see figure 2).



Figures 2 Dimension of Sustainability in a Lean Environment

1) Principle of Waste Reduction

The LM aim of zero waste and, as a result, Energy efficiency contributes to pollution avoidance and reduction (Florida, 1996, King and Lenox, 2001). To improve additional value for the customer, one of the ultimate principles of LM is to reduce and/or eliminate any process that adds value along the product value cycle. Lean allows you to achieve more with less—less human labor, less equipment, less time, and less space—while coming closer to stable outlook what your consumers want. It also makes work more enjoyable by offering real-time information on efforts to transform muda (waste) into value (Womack et al., 2003), p.15). Muda means "waste" in Japanese, and it refers to any human activity that consumes resources but produces no value: mistakes that need to be corrected, development of items that no one wants, causing inventories and remaindered goods to accumulate, processing processes that aren't truly needed, staff mobility and goods transit from one area to another for no purpose, and huddled groups of individuals. (Womack & Jones, 2010)

Similarly, waste reduction and/or elimination via the reduction or avoidance of environmental contamination and the reduction of waste at its source is a major problem for environmental sustainability. This is perhaps the most straightforward and obvious approach to implement sustainable behaviors. Since the 1990s, when offices involves buying empty cans for recycling, the effort has enlarged to include waste mitigation in article (tree and forest habitat conservation), quality control of products (reworking or facilitating change that use less raw domestic waste less material in the manufacturing of goods), and changing out incandescent lights for LED lights (higher efficiency). Sonoco Sustainability Solutions (S3) has set a target to decrease the amount of trash that ends up in landfills. Sonoco intends to create client programs to help them minimize the amount of waste they generate. S3 will come up with novel ways to repurpose trash in order to produce a new cash stream. This initiative can help Sonoco's manufacturing clients save money by reducing waste and repurposing it. (Staff, 2007). This initiative can help Sonoco's manufacturing clients save money by reducing waste and repurposing it.

2) Principle of process-centered attention

The rationale of focusing on waste reduction at the point of origin is comparable to that of attaining quality across all phases of the process, which is one of the origins of LM. The Lean emphasis is concerned that not just addressing the problem is insufficient, but also preventing it from recurring in the future. Similar to the environmental strategy, which emphasizes environmental effect prevention rather than adopting remedies when the consequences are irrevocable at the end of the process (King and Lenox, 2001, Sawhney et al., 2007).

3) Involvement and participation of a large number of individuals is a key element

Another important aspect of the LM foundation is people's engagement in the management system. This engagement is also necessary for adopting environmental practices and tools/techniques in the environmental emphasis. Advanced human resource management techniques (versatile personnel, worker engagement in job standardization, cooperation, and the establishment of improvement groups) and an organizational culture of continuous improvement can help organizations implement environmental management concepts and practices (Rothenberg et al., 2001, Soltero and Waldrip, 2002). Upon this one hand, there is empirical evidence from a variety of sources (Rothenberg et al., 2001, Jabbour et al., 2013) shows that lean companies foster green manufacturing principles and one of the important success factors in green transformations is to proactively implement environmental management strategies to improve environmental performance. Lean manufacturing is a targeted operation for profit-driven enterprises to establish sustainable business models for led to the declaration, eliminating waste, enhancing material efficiency, and value creation. Value stream mapping is a set of lean tools for identifying material flow and waste in long-term manufacturing processes, as well as evaluating opportunities for improvement in order to provide greater value to consumers (Rother and Shook, 2003). On the other hand, according to scientific data, lean concepts and practices are basically the key to supporting the accomplishment of environmental goals and improvements in environmental outcomes (Gordon, 2001, King and Lenox, 2001, Vinodh et al., 2011). The combination of the lean and green system models creates a structured and holistic mechanism for turning a business green , and thus could be used as a potential sustainable business model to achieve the best results in an organization's economic and environmental performance. Adopting lean and green techniques has substantial benefits in terms of raw material reduction, utility footprint reduction, and cost reduction (Sobral et al., 2013, Zokaei et al., 2016). In this regard, the major contribution of study literatures reflecting on the last two decades of lean and green practices linked to which lean and environmental principles (Martínez-Jurado and Moyano-Fuentes, 2014). The research framed three principles using the ideas of Lean and Green or Environmental.

Tables 8 Key contribution and area of application of the paper’s analysis on lean management and sustainability which related with lean and environmental principle

Author/s	Area of application	Key contribution	Lean and Environmental Principle (Martínez-Jurado and Moyano-Fuentes, 2014)		
			Waste Reduction	Process centered Focus	High people involvement
(Maxwell et al., 1993)	Automotive	LM has a positive impact on the adoption of environmental ideas and practices (as a driver/facilitator).	*	*	
(Cusumano , 1994)	Theoretical	JIT delivery have a (bad) impact on several environmental consequences (higher urban congestion and environmental pollution). Lean firms, on the other hand, implement environmental measures proactively in order to reduce pollution.	*		
(Florida, 1996)	Multisectoral	The effect of LM on environmental outcomes. Positive impact, mostly on resource efficiency, pollution avoidance, and reduction.	*	*	
(Pojasek, 1999)a	Theoretical	The 5S (Lean tool) has been adapted for use in environmental principles and		*	

		practices.		
(Pojasek, 1999)b	Theoretical	Waste reduction (Lean principle) and pokayoke (Lean tool) are being adapted for use in environmental concepts and practices.	*	*
(Gordon, 2001)	Multisectoral	Synergies between LM and green efforts are being investigated. Transition guidance for LM & Green implementation (examples of "Success Stories").		*
(King and Lenox, 2001)	Multisectoral	The effect of LM on environmental outcomes. Positive impact, mostly on resource efficiency, pollution avoidance, and reduction. The adoption of environmental ideas and practices is facilitated by LM (as an intrinsic facilitator).	*	
(Rothenberg et al., 2001)	Automotive	The effect of LM on environmental outcomes. Some environmental indicators suffer as a result of the negative impact (reduction of VOCs). Resources are used more efficiently as a result of this. There are several disagreements between LM and Green. LM, on the other hand, makes it easier	*	

		to adopt environmental management concepts and practices on a proactive basis.		
(Soltero and Waldrip, 2002)	Theoretical	Potential synergies between LM and Green are being investigated. The adoption of environmental concepts and practices is facilitated by lean culture. Kaizen (continuous improvement) events are being adapted for incorporation with environmental concepts and practices.		*
(Simons and Mason, 2003)	Theoretical	VSM must be adapted in order to be integrated into environmental concepts and practices. Focus on internal and external LM.		*
(Larson and Greenwood, 2004)	Theoretical	Potential integration between LM and Green are being investigated. As a result, LM encourages the adoption of environmental concepts and practices, resulting in lower pollution levels. Adopting a strategic approach for combining LM and Green efforts is critical (great opportunities).	*	

(Simpson and Power, 2005a)	Automotive	LM, Lean Supply, and environmental practices are being integrated into a theoretical model. Synergies and tensions between LM and Green efforts are investigated.		*
(Corbett et al., 2006)	Theoretical	Although LM naturally aids in the development of environmental outcomes, it is critical to have a strategic emphasis for combining LM with Green efforts (great opportunities). Synergies and tensions between them are studied.		*
(Venkat and Wakeland, 2006)	Generic food supply chain	The generic supply chain was simulated to show the conflicts between lean and green, trade-offs, and other potential for process optimization.		*
(Sawhney et al., 2007)	Metal-working	The creation of a methodology for evaluating the link between LM principles and practices and their influence on environmental outcomes (metrics framework).	*	
(Mason et al., 2008)	Theoretical	VSM must be adapted in order to be integrated into environmental concepts and practices. More emphasis on		*

		supply chain management.		
(Moreira et al., 2010)	Theoretical	Inadvertently, LM enhances several environmental outcomes. Adopting a strategy focus for combining Lean and Green efforts is critical (great opportunities).	*	*
(Taubitz, 2010)	Theoretical	Theoretical framework for combining LM, environmental, and safety concerns. The implementation of Green and Safety initiatives is aided by a lean culture.		*
(Esmemr et al., 2010)	Shipping and logistic	Simulated the process to determine the best number of machines to use in order to minimize environmental effect.		*
(Miller, 2010)	Furniture	Integrated lean tools and sustainability concepts with discrete event simulation modeling to investigated manufacturing process by suing mathematic optimization to choose the right source to reduce shipping distance (and thus carbon footprint) and make significant cost savings		*

(Mashaei et al., 2011)	Cyclic pallet system	To minimize energy consumption in the pallet system, utilize an optimization model that employs optimization principles.	*	
(Espadinha-Cruz et al., 2011)	Automotive	Model for assessing business interoperability and recommending steps to avoid supply chain problems.		*
(Saurin et al., 2011)	Supply chain	Using the balanced scorecard technique model merging lean and green supply chains into a performance appraisal system		*
(Carvalho et al., 2011)	Theoretical	A study of the literature on possible synergies and tensions between LM and Green from an internal and supply chain perspective.		*
(Vinodh et al., 2011)	Theoretical	Creating a model for integrating LM and environmental projects (joint implementation). Making the switch from 5S to 7S (safety & sustainability).		*
(Yang et al., 2011b)	Multisector	The effect of LM on environmental outcomes. The adoption of environmental activities mediates this link. To overcome the tensions between LM and environmental performance, it is critical to		*

		provide resources to green activities. The adoption of environmental management techniques is favorably connected to a previous LM endeavor.		
(Sorli et al., 2012)	Multisector	The Lean Product and Process Development Model combines the life cycle of a product with sustainability and cost effectiveness to produce value.	*	*
(Ho, 2012),	General	The SIRIM Green 5-S Model for Sustainable Development/Integrated Lean Management System was created with the goal of reducing waste, improving processes, and saving money.	*	*
(Cabral et al., 2012)	Auto-maker supply chain	Agile, Lean, and Integrated. The use of the Resilient and Green (LARG) analytic network process (ANP) model to help decision-making in supply chain businesses aided the process of choosing acceptable practices and key performance indicators.		*

(Zamri et al., 2013)	Automotive	To show the link between Green Lean Six Sigma (GLSS) and Financial Performance (FP), a model based on structural equation modeling was employed.		*	
(Camacho-Miñano et al., 2013)	Automotive	Integration of lean and green initiatives using a discrete event simulation model into a manufacturing system is a technique for combining both lean and green strategies into a manufacturing system.		*	
(Fercoq et al., 2016)	General	A waste management approach that combines lean and green principles to focus on continual waste minimization.	*		
(Jabbour et al., 2013)	Automotive	When compared to the effect of various HR practices on EM practices, LM has a larger influence on EM practices.		*	*
(Aguado et al., 2013)	Metal-working	Development of a technique that focuses on LM and Green synergies. Evaluation of the improvements made.		*	

(Hajmohammad et al., 2013)	Manufacturing plants	The connection between LM, Supplier Management (SM), Environmental Practices, and Environmental Performance has been investigated. The degree to which Environmental Practices are implemented mediates the link between LM and SM, as well as Environmental Performance. Environmental practices moderate the influence of LM and, to a lesser extent, SM on environmental performance.	*	
(Wong and Wong, 2014)	Semiconductor	The 'Lean-ecosphere' management system employs interpretative structural modeling and an analytical network approach to build a solid basis for lean management utilizing scientific methods while taking into account human factors.	*	*
(Pampanelli et al., 2014)	Automotive	The manufacturing plant cell was thoroughly examined using the Lean & Green Model.	*	
(Zailani et al., 2015)	Automotive supply chain	Interconnections between lean, green, and supply chain management were discovered using an interpretive structural	*	

		model to classify their "driving of dependency power."		
(Fahimnia et al., 2015)	Multisector	Using a sophisticated mathematical modeling method, the transfer across cost and environmental deterioration via carbon dioxide emissions, energy use, and waste generation were examined using a supply chain model.	*	
(Ng et al., 2015)	Metal stamp part producer	CVE (Carbon-Value Efficiency) is an easy-to-measure statistic that combines lean and green practices.	*	
(Piercy and Rich, 2015)	Multisector	In the process, to demonstrate the connectedness of lean-sustainability and holistic change, a stage-based theory of lean sustainability was used. This could be used to measure an organization's performance as a standard measure.		*
(Wu et al., 2015)	Automobile (auto-fashion)	Integrated sustainable practices model integrating the most popular lean green, and social practices, as well as their cumulative impact on the triple bottom line, as opposed to executing the activities		*

		individually.		
(Greinacher et al., 2015)	Metal	The comprehensive lean and green assessment of production systems used a parallel programming tool for monetary evaluation of lean and green production system combining energy and material utilization.	*	*

2.12.3 Environmental sustainability methods that are lean

In terms of lean environment sustainability practices, a study model was established that envisioned lean manufacturing and a number of its best lean manufacturing practices that characterize distinct sectors of the firm (Panizzolo 1998). Second, examine the study of lean and green (Fliedner, 2008), which focuses on the use of various lean techniques to improve operations and save money while also providing environmental advantages through waste reduction and elimination. Third, assess the environmental impact of adopting lean operating techniques (Piercy and Rich, 2015) research that implementing lean operational practices has on the environment. Fourth, while studying literature, check the selection of lean manufacturing methods based on the most frequent practices. Finally, use the research frame of (Martínez-Jurado and Moyano-Fuentes, 2014) to evaluate the link between lean manufacturing techniques and lean and environmental principles (see Figure 3).

1. Panizzolo Model 1998
- The finest lean techniques in the company's many departments

2. Fliedner Model 2008
- Lean tools help to optimize operations by reducing waste and demonstrating environmental advantages.

3. Piercy and Rich Model 2015
- Adoption of lean methods that have an influence on the environment

4. The reserach study
- In examining literature, check the selection of lean techniques based on the most frequent practices.

5. Martínez-Jurado and Moyano-Fuentes, 2014
- Examine the link between practices and the Lean and Environmental Principles.

Figures 3 This study's lean environmental sustainability methods

1) Panizzolo Model, 1998

The Panizzolo model was used to modify practices in this study, which consisted of 26 practices in the areas of process and equipment, production planning and control, product design, human resources, customer connections, and supplier relationships. The quality area, on the other hand, is not included in the intervention (Panizzolo, 1998, Wong et al., 2009). Nordin et al. (2010) utilized the Panizzolo framework to analyze the extent to which lean manufacturing methods have been implemented in the Malaysian automobile sector.

Tables 9 Panizzolo framework for optimal lean manufacturing processes in many sectors of the firm in terms of lean environmental sustainability principles

No.	Area	Code	Lean manufacturing practices
1.	**Process & Equipment**	PE1	Kaizen
		PE2	5S
		PE3	Setup time reduction

	PE4	Cellular manufacturing
	PE5	Continuous flow
	PE6	Equipment layout
	PE7	Product design – simplicity
	PE8	Error proof equipment
	PE9	Preventive maintenance
2. Manufacturing planning & control	MC1	Levelled production
	MC2	Kanban/ pull production
	MC3	Daily schedule adherence
	MC4	Small lot size
	MC5	Visual control
3. Human resources	HR1	Group problem solving
	HR2	Training
	HR3	Cross functional teams
	HR4	Employee involvement
	HR5	Workforce commitment
4. Supplier relationships	SR1	JIT delivery
	SR2	Supplier quality level
	SR3	Supplier involve in quality improve
	SR4	Supplier involve in product design
5. Customer relationships	CR1	Customer involve quality programs
	CR2	Customer involve in product design
	CR3	JIT link

2) Fliedner Model, 2008

According to (Fliedner, 2008), the company employs a variety of lean methodologies and technologies to enhance operations and save money by reducing and eliminating waste. (see Table 10)

Tables 10 Lean Tools and Methodologies with Environmental Benefits

Lean manufacturing practices	Environmental Benefits
1. Kaizen Events	Identifying and removing hidden wastes and waste-producing activities.
2. Value Stream Mapping	Lean production's environmental advantages (e.g., decreased waste from fewer errors, scrap, and energy use) are amplified across the network.
3. 5S	Clean windows minimize the amount of light required. Spills and spills are detected faster.
4. Cellular Manufacturing	- Reducing set-up times saves energy and resources. - Fewer product changes mean less energy and resource use.
5. Pull Approach	Reduces in-process and post-process inventory; reduces waste from damaged, spoilt, or degraded items.
6. Total Preventive Maintenance	Increased equipment lifespan reduces the need for replacement and the related environmental consequences.

7. Six Sigma	- Fewer faults mean less energy and resources are used, and waste is avoided. - Emphasizes the importance of minimizing the circumstances that lead to accidents, spills, and malfunctions, resulting in less solid and hazardous wastes.
8. Pre-production Planning	- At the product and process design stage, comparable to "Design for Environment" techniques, reduces waste. - Using the right-sized equipment reduces material and energy use. - Reduced production processes complexity (also known as "design for manufacturability") might eliminate or simplify process stages; ecologically sensitive activities, for example. which are frequently time, resource, and capital-intensive, can be targeted for removal.
9. Lean Supplier Networks	Lean production's environmental advantages (e.g., decreased waste from fewer errors, scrap, and energy use) are amplified across the network.

3) Piercy and Rich Model, 2015

According to (Piercy and Rich, 2015), the adoption of lean operational techniques, as well as business approaches connected to sustainability and corporate profitability, is on the rise. Kaizen, 5S, setup time reduction, cellular manufacturing, equipment layout, TPM, Kanban, JIT, and supplier relationships are all examples of lean manufacturing that help both lean and sustainability.

4) Examine the link between practices and the Lean and Environmental Principles

The following fundamental principles connect to the ideas of lean environmental sustainability discussed in the study: a) Waste reduction principle b) Process-centered-focus principle c) High-level engagement and involvement of people In the waste reduction concept, there are eighteen lean environment sustainability practices, fifteen lean environment sustainability practices in the process center emphasis, and sixteen lean environment sustainability practices in high levels of people involvement and participation (see Table 11 and Table 12)

Tables 11 Lean environmental sustainability practices base on principles

No.	Principle	Lean Environment Practices
1.	Waste Reduction	Kaizen practice on environment waste
2.	Waste Reduction	5S reduction of waste, waiting, searching
3.	Waste Reduction	Set up time reduction reduce material losses
4.	Waste Reduction	Cellular manufacturing reduce material
5.	Waste Reduction	Pre production planning reduce material
6.	Waste Reduction	TPM reduce waste and cost
7.	Waste Reduction	Kanban practice reduces waste and scrap
8.	Waste Reduction	POUS reduce waste of non-value activities
9.	Waste Reduction	Heijunka inventory reduction
10.	Waste Reduction	Continuous flow reduce scrap or backflows
11.	Waste Reduction	Take time to prevents buildups inventory
12.	Waste Reduction	Minimum lot size reduces WIP
13.	Waste Reduction	Store buffer & safety stock reduce inventory
14.	Waste Reduction	FIFO with Kanban reduce inventory
15.	Waste Reduction	Supplier involve new product design

16.	Waste Reduction	Supplier implement innovative material
17.	Waste Reduction	Supplier joint approach to problem solving
18.	Waste Reduction	Supplier collaborative in quality improve
19.	Process Center Focus	Kaizen focus on rapid process improvement
20.	Process Center Focus	5S help shop floor to standardized work
21.	Process Center Focus	Set up time reduction help convert process
22.	Process Center Focus	Cellular manufacturing efficient processing
23.	Process Center Focus	Pre production planning reduce complexity
24.	Process Center Focus	TPM in continuous improvement target
25.	Process Center Focus	Kanban cards pull material
26.	Process Center Focus	Heijunka working together balance fashion
27.	Process Center Focus	Takt time focus in production line
28.	Process Center Focus	Store buffer & Safety stock help production
29.	Process Center Focus	Continuous flow synchronization
30.	Process Center Focus	Minimum lot size to variability in system
31.	Process Center Focus	Standard inventory reduce variation
32.	Process Center Focus	POUS with proper 5S and transparency
33.	Process Center Focus	Supplier improve product design
34.	High People Involvement	Kaizen require team involvement
35.	High People Involvement	5S gain creative input from staff
36.	High People Involvement	SMED involve manpower
37.	High People Involvement	Cellular manufacturing people involvement
38.	High People Involvement	Pre production planning people involvement

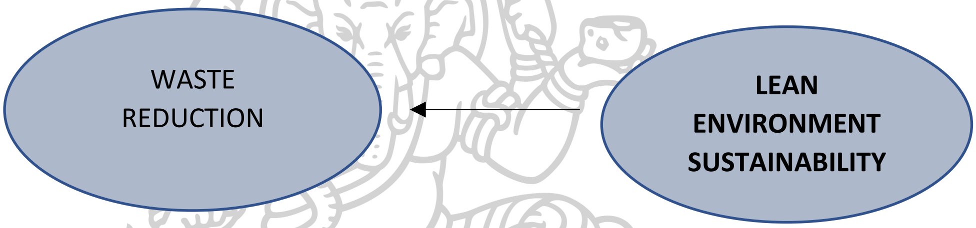
39.	High People Involvement	TPM optimized employees' performance
40.	High People Involvement	Kanban rules to tell operators what to do
41.	High People Involvement	Heijuka operator are important element
42.	High People Involvement	Takt time reflect number of worker hour
43.	High People Involvement	Continuous improvement worker practice
44.	High People Involvement	Minimum lot size worker practice
45.	High People Involvement	POUS involve employee
46.	High People Involvement	Continuous flow worker better perform
47.	High People Involvement	Existing supplier response environment
48.	High People Involvement	Provide incentive to supplier to reach target
49.	High People Involvement	Long term strategy to assess supplier operate

Tables 12 Literature-based ideas underpin lean environmental sustainability approaches

Area	Practices : Direct positive LM to environment Sustainability	Lean and Environment Sustainability → Principle (Definition): 1) Waste Reduction	2) Process centered Focus	3) High level of people involvement and participation	Lean: Panizzolo (1998)	Lean&Green: Gene Fliedner, (2008)	Lean & Susainability: Piercy, Niall Rich, Nick (2015)	Lean benefit	sustainability benefit
Process & Equipment	1. Kaizen	*	*	*	*	*	*	engage workers, find solutions to problems	engage workers, improved workplace
	2. 5S	*	*	*	*	*	*	Improve quality/layout/safety	Improve safety, improved ease of work life
	3. Set up time reduction	*	*	*	*	*	*	Run smaller batches	Reduce material losses from changeover (waste)
	4. Cellular manufacturing	*	*	*	*	*	*	Productivity improvement. Reliability improvement.	Less energy consumption. Less material consumption. Less pollution/waste.
	5. Equipment layout (3P)	*	*	*	*	*	*	More efficient/quality layout	Better, safer working environment
	6. TPM	*	*	*	*	*	*	Focuses on wastes and cost	Focuses on waste reduction based on machine
Manufacturing Planning & Control	1. Kanban	*	*	*	*	*	*	regularise system (cost)	reduce material waste
	2. JIT (Pull approached)	*	*	*	*	*	*	regularise system (cost)	reduce material waste
	2.1 Production leveling (heijunka) or Balanced operations								
	2.2 Continuous Flow								
	2.3 Takt time								
	2.4 Minimum lot sizes (batch size)								
	2.5 Store (Cycle) / Buffer / Safety Stocks								
	2.6 Standard inventory								
	2.7 Point of use storage (POUS)								
Supplier Relationship	1. Eliminating waste of excess inventory	*			*	*	*	Long term commitment from supplier to company for quality/cost improvement. Joint problem solving and development	Better control of sustainability actions of supplie
	2. Reduction of waste through fewer defects, less scrap, and less energy usage	*			*	*	*		
	3. Reduction in the risks associated with chemical management and storage		*		*	*	*		
	4. Respond more rapidly to issues of environmental performance in suppliers			*	*	*	*		

1. Principle of Waste Reduction

There are eighteen lean environment sustainability strategies that result in positive waste reduction, including: 1) Kaizen, 2) 5S, 3) Set up time reduction 4) Cellular manufacturing, 5) Pre production planning, 6) TPM, 7) Kanban practice, 8) POUS, 9) Heijunka, 10) Continous flow, 11) Takt time, 12) Minimum lot size, 13) Store buffer & safety stock, 14) FIFO, 15) Supplier involve new product design, 16) Supplier implement innovative material, 17) Supplier joint approach to problem solving, and 18) Supplier collaborative in quality improve (see Figure 4. and Table 13)



Figures 4 Principle of waste reduction in a lean workplace for long-term sustainability

Tables 13 Waste Reduction Practices

No.	Principle	Lean Environment Practices
1.	Waste Reduction	Kaizen practice on environment waste
2.	Waste Reduction	5S reduction of waste, waiting, searching
3.	Waste Reduction	Set up time reduction reduce material losses
4.	Waste Reduction	Cellular manufacturing reduce material
5.	Waste Reduction	Pre production planning reduce material
6.	Waste Reduction	TPM reduce waste and cost
7.	Waste Reduction	Kanban practice reduces waste and scrap

8.	Waste Reduction	POUS reduce waste of non-value activities
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13.	Waste Reduction	Store buffer & safety stock reduce inventory
14.	Waste Reduction	FIFO with Kanban reduce inventory
15.	Waste Reduction	Supplier involve new product design
16.	Waste Reduction	Supplier implement innovative material
17.	Waste Reduction	Supplier joint approach to problem solving
18.	Waste Reduction	Supplier collaborative in quality improve

1) Kaizen in waste reduction principle

Kaizen comes from the Japanese words kai, which means "to dismantle," and Zen, which means "to put back together." Kaizen is founded on the basics of dismantling something and learning how it works in order to improve it. Reduced waste, increased productivity, and long-term growth in a company's specialized systems and activities are all priorities. Kaizen means "constant improvement" in Japanese. Kaizen is a philosophy or belief system as well as a technique for altering or improving behavior, according to (Robert PhD, 2014), Identifying and removing hidden wastes and waste-producing activities (Fliedner, 2008). The team evaluates the process to be improved and classifies it as either value-adding, non-value-adding, or required non-value-adding (Martin and Osterling, 2007). In response to (Kidwell), , he stated that numerous proposals for increasing manufacturing efficiency decrease or eliminate a variety of wastes. Even if environmental wastes aren't given first attention, it's probable that lean will handle them later. As indicated in the EPA's 2003 study, this can happen as a result of lean efforts that aren't purposefully concentrating on environmental wastes. Companies may, however, opt to concentrate kaizen on certain “environmental” wastes. Lean manufacturing provides tangible benefits by lowering production costs and maximizing capital use. If environmental concerns are included in lean manufacturing, it may assist a firm accomplish many other long-term goals, such as environmental sustainability and maintaining a positive public image. As a result, it is easier to keep working to eliminate all types of waste, which will eventually aid the firm in achieving flow, pull, and excellence.

2) 5S in Waste Reduction Principle

The 5s is a Lean Toolbox item that focuses on workplace preparedness. Many lean technologies, Visual management, TPM, and standard works, for example, cannot be applied without 5s; these tools are critical for minimizing wastes, increasing flow, and supporting in the establishment of a pull system (Halim et al., 2014). The illumination requirements are reduced when the windows are clean. When spills and leaks are detected more quickly, less materials and chemicals are consumed, and equipment, components, and materials are organized and simple to discover, (Fliedner, 2008) the relationship between lean and green of 5S activity is established. In relation to (Piercy and Rich, 2015), 5S provides reciprocal advantages to LM in terms of better quality, layout, safety, and sustainability, as well as increased safety and convenience of work life. According to Kilpatrick (2003), 5s is one of the simplest Lean techniques to deploy, provides an immediate return on investment, is applicable to all industries, and may be used to any function inside a company. Because of these traits, it's usually our first recommendation for a company adopting Lean.

The 5 S’s stand for Sort, Set to order, Shine, Standardize, and Sustain (Moulding, 2010).

1. S1-Sort - Seiri (Organization), the goal is to reduce waste and loss by identifying what is required and what is not, and getting rid of what is not.
2. S2-Set in Order-Seiton (Neatness), the goal is to enhance efficiency via the practice of orderly storage, so that the correct item may be chosen effectively (without waste) at the right moment, and everyone has easy access to it. Everything has its place, and everything is in its place.

3. S3-Shine-Seiso (Cleaning): The goal is to monitor, examine, and rectify to produce a clean worksite free of waste, dirt, and dust so that issues (leaks, spills, excess, damage, etc.) may be recognized more readily. The goal of this task is to figure out what's causing the dirtiness and how to fix it.
4. The goal of S4-Standardization-Seiketsu is to eliminate variations in order to support 'visual management,' set norms for a tidy, clean workplace and standardization of guidelines, and then to maintain each area consistent with each other.
5. S5-Sustain-Shitsuke (Discipline), the goal is to maintain and train in order to build standards throughout time, with the workplace organization serving as the key to success.

According to (Filip and Marascu-Klein, 2015), the benefits of providing a quality-conducive working environment, minimizing obvious faults, blunders, and difficulties, decreasing waste, lowering waiting and searching time, visibility and clarity of flow and environments, and creating standards are all part of the 5S technique (everyone knows exactly where to find things).

3) Reduce the amount of time spent on waste reduction under the Waste Reduction Principle

Smaller batch sizes necessitate more frequent setups. As a result, decreasing setup time (and cost) is becoming increasingly important in order to service consumers in a timely and profitable manner. (R. and F., 2009).

SMED (Single minute exchange of dies) / OTS (One touch set up)

One of the numerous lean production strategies for minimizing waste in a manufacturing process is SMED (single minute exchange of dies). The term "single" refers to a time interval of fewer than 10 minutes. It enables a manufacturing process to quickly and efficiently transition from one product to the next. From process and packaging plants to airplanes, the core principles of SMED have been utilized to minimize setup and turnaround time in many sorts of manufacturing, assembly, and even service sectors (Shingo, 1996). Shigeo Shingo, a Japanese industrial engineer, developed SMED to help companies substantially reduce changeover times. The essence of the SMED system, according to (Shingo, 1996), , is to convert as many changeover processes as feasible to "external" (done while the equipment is running), while simplifying and streamlining the remaining steps. Dave (Dave and Sohani, 2012) describes the SMED process as follows:

1. Examine the existing approach: All of the changeover operations are now routinely recorded on video tape. It covers the complete changeover from one model to another model.
2. Separate internally and externally activities: Internal activities can only be carried out when the process is stopped, but external activities can be carried out while the previous batch is being produced or after the following batch has begun.
3. Streamline the switch process: For each iteration of the aforesaid process, a significant amount of time should be set aside.
4. It's reasonable to expect a reduction in setup times, thus crossing the ten-minute threshold may require multiple repetitions.
5. Ongoing Training: Following the successful initial iteration of the SMED application, the most important task is to teach all of the cell's operators. Cell champions have provided training (Master of Changeover). Changeovers in SMED are built up of steps called "elements." Elements are divided into two categories.
6. External element: That component of the setup that may be completed while the machine is running, such as prepping a die for the next run(Rubrich and Watson, 2004).
7. Internal element: That component of the setup that must be completed when the machine is turned off, such as die removal or attachment (Rubrich & Watson, 2004).

The SMED method focuses on externalizing as many aspects as feasible, as well as streamlining and simplifying all elements.

With speedier changeovers, smaller batch sizes are possible. Each of these seven fundamental motion elements has its own set of codes and time values. These fundamental elements, as well as the cycle for the time values of the elements, may simply describe an operation. This procedure may be readily calculated by just adding the numbers together. With a stopwatch and/or videotape to employees, each setup action is timed and logged (Wisconsin Manufacturing Extension Partnership, (Cakmakci and Karasu, 2007) MTM-UAS). As a result, without SMED, further lot size reductions will be impossible (faster changeovers enable more frequent product changes). In addition, a successful SMED program will result in lower manufacturing costs (faster changeovers mean less equipment downtime), improved customer responsiveness (Small batch sizes allow for more flex time), lower inventory levels (smaller lot sizes mean lower inventory levels), and a quicker starting (standardized changeover processes improve consistency and scalability) (Shingo, 1996). According to (Dave and Sohani, 2012), SMED may be used in conjunction with other lean tools to enhance not just mechanical processes but also procedural and organizational processes, as well as save personnel, which is one of the most valuable resources in the company. According to (Piercy and Rich, 2015), lowering set-up time offers mutual advantages to LM in terms of the factory being able to run in smaller batches, as well as sustainability benefits of reducing material losses from changeover, which implies less waste. Other advantages of a successful SMED program include cheaper production costs (faster changeovers imply less downtime), decreased inventory levels and enhanced customer response (smaller batch sizes allow for much more flexible scheduling) (smaller lot sizes result in lower inventory levels) (Shingo, 1996).

4) The Principle of Cellular Manufacturing in Waste Reduction

Regarding (Piercy and Rich, 2015), the advantages of cellular manufacturing in LM include quality improvement, cost reduction, increased productivity, and increased dependability. Operating cellular manufacturing has the following benefits: reduced energy consumption, less material consumption, and less pollution/waste. Energy and resource consumption are reduced as a result of shorter set-up periods and fewer product changes (Fliedner, 2008). The operator performs extra manual duties, such as direct quality assurance after each sub-process to halt improperly manufactured components immediately or basic maintenance chores to maintain high dependability, in accordance with the lean concepts of zero-defects and autonomous maintenance. The pieces are transported manually, resulting in a one-piece flow of the product. By placing the devices adjacent to one other, transport distances may be kept to a minimum. Both characteristics help to minimize stockpiling and promote quick throughput. Only a limited amount of work-in-progress stock is permitted (Metternich et al., 2013, R. and F., 2009). The application of Lean Manufacturing principles to cellular manufacturing results in highly adaptable production systems. Separating single activities and equally distributing them is a key condition for enabling flow. Naturally, this is easier for assembly processes, because volume fluctuations may be accommodated with less effort by hiring the appropriate number of workers. The use of various levels of automation in conjunction with the separation of job contents.

5) Waste reduction principle: pre-production planning

Production processes are groups of people, machinery, and procedures that work together to complete a company's industrial operations (Cochran et al., 2000, Groover, 2001, Matt, 2008). Every system, according to system theory, may be defined as a collection of subsystems (Züst and Schregenberger, 2003). Individual subsystems are interconnected, function under common causes, and must be built in concert for optimal efficiency (Houshmand and Jamshidnezhad, 2002).

A manufacturing system is a collection of production subsystems that together make up the entire production flow from raw material to the customer's hands via a company's value streams. (Erlach, 2005). (Matt, 2008) used the term "production module" to define a production subsystem as a manufacturing or assembly process or cell through which material flows. As a result, whenever processes are separated and material flow stops, the system boundary of a production module comes to a halt (Matt, 2008). There is buffer stock at this stage, and the product is generally differentiated farther downstream (Naylor et al., 1999, Christopher and Towill, 2000). As either a result, the goal of this research is to see how pre-production planning affects the final output in lean techniques on environmental advantages in accordance with lean and environmental principles. The benefits of combining lean and sustainability by adopting the re-production planning approach include a more efficient quality layout and a better, safer working environment, according to (Piercy and Rich, 2015). A manufacturing system is a collection of production units that together make up the entire production flow from raw materials or components to the customer's hands via a company's value streams. (Erlach, 2005). The word "production module" is used to define a manufacturing or assembly process or cell through which material flows. As a result, whenever processes are separated and material flow stops, the system boundary of a production module comes to a halt (Matt, 2008). Pre-production planning, which forms the complete production flow from raw materials or components into the hands of the customer (Fliedner, 2008, Erlach, 2005), is one of the lean techniques and instruments with related environmental advantages (Fliedner, 2008, Erlach, 2005). It eliminates waste throughout the product and process design stages, comparable to “Design for Environment” approaches that reduce material and energy needs by using the right-sized equipment.

6) TPM is a waste reduction principle

TPM (Total Productive Maintenance) (Kanta Patra et al., 2005) A novel approach to equipment and facility management is total productive maintenance. TPM is a routine maintenance program based on a newly defined concept for keeping plants, equipment, and facilities in good working order (Gupta et al., 2006). TPM stands for: Total: Indicates that all functions and personnel at all levels of the hierarchy are involved. Productive: Emphasizes the effective and efficient use of all resources. Maintenance refers to the process of keeping man-machine-material systems in good working order. TPM is therefore a means of effecting change. When correctly executed by people and teams, It's a series of measures taken on a regular basis that can lead to better plant asset management (Robinson and Ginder, 1995). TPM is philosophically similar to total quality management (TQM) in some ways, for example, upper-level management must be fully committed to the initiative. Employees must be empowered to take corrective action, and a long-term mindset must be adopted, as TPM can take a year or more to establish and is an ongoing process. Changes in employee attitudes about their work obligations are also required. The systematic execution of maintenance by all personnel through small group activities is known as TPM (Gupta et al., 2006). TPM has two major objectives: to create ideal circumstances for the workplace to function as a human-machine system and to increase the workshop's overall quality. To improve machine performance, TPM relies on proactive and progressive maintenance techniques, as well as the expertise and collaboration of operators, equipment suppliers, engineering, and support staff. Kilpatrick (Kilpatrick, 2003). Its goal is to increase the overall equipment effectiveness of any asset used in the manufacturing of products and services (Wireman, 2004). As a result of this modern manufacturing technique, breakdowns are minimized, unscheduled and planned downtime is decreased, utilization is improved, capacity is increased, and product quality is improved. Cheaper operating expenses, longer equipment life, and lower total maintenance costs are among the benefits (Kilpatrick, 2003). As a result, TPM activity is a strategy that a firm may use to maintain a competitive advantage by adhering to three Lean and environmental sustainability principles. The benefits of TPM in lean and sustainability, according to (Piercy and Rich, 2015) , assist the company in focusing on waste reduction and cost-cutting initiatives. Increased equipment lifetime reduces the necessity for replacement equipment and the consequences for the environment, as well as a reduction in the quantity and severity of spills, leaks, and upset conditions: less solid and hazardous waste (Fliedner, 2008).

7) The idea of Kanban in waste reduction

This is a technique for keeping stuff flowing in a controlled manner. Resource order points, the amount of material required, where the material is ordered, and where it's being delivered are all factors to consider are all shown on Kanban cards (Kilpatrick, 2003). Toyota utilized kanban to cut expenses and control equipment usage in the beginning. Toyota, on the other hand, continues to utilize the system not only to control costs and flow, but also to identify bottlenecks and possibilities for continual development (Gross and McInnis, 2003). Operators utilize visual cues to decide how much they run and when they stop or change over using Kanban scheduling. The Kanban rules also instruct the operators on what to do in the event of an issue and who to contact in the event of a problem. It is a visual indication that helps managers and supervisors to quickly see the line's scheduling status. The Lean Enterprise Institute claims that (www.lean.org). Creating Level Pull, a workbook on how to establish a level, pull-based production control system, is written by Art

Smalley. The following are the three types of signal kanban: 1. pattern creation, 2. lot creation using a batch board, and 3. Triangle Kanban.

1. Pattern production: Establishes a set sequence of production as well as certain fundamental guidelines for lot sizes, which may be adjusted as needed. The basic pattern or sequence of production, on the other hand, is always preserved. This results in a set manufacturing sequence (i.e., pattern) that is always repeated. This type of manufacturing is frequently required in heat treatment, paint, and other processes that need particular changeover sequences. While the product sequence may be set in these situations, the actual volume produced at each stage of the cycle is not and changes based on client demands. A fixed order/unfixed quantity replenishment cycle is what this is called. Pattern manufacturing creates a fundamental production rhythm and sequence. The method works as long as the overall manufacturing pace is kept near to the end assembly takt time and the market regulates the pull between the two processes. It's the initial stage in setting up a production control and pull system between two operations separated by a market.

2. Lot creation using a batch board: For each container of components in the system, create a physical Kanban. As material from the market is used, the Kanban cards are instantly removed and regularly returned to the upstream batch-producing process, where they are displayed on a board that emphasizes all part numbers and shows an outlined shadow space for each of the Kanban cards in the system. This strategy has a number of advantages. One is that, unlike pattern manufacturing, the scheduling sequence is more variable. Second, it shows inventory consumption in a graphic format and identifies potential difficulties in the central market.

3. Triangle Kanban: The triangle Kanban is the way that Toyota facilities use most of the time to connect a batch operation to a downstream assembly process.

According to the Pull Replenishment technique (Kumar et al., 2012) , The Kanban (or Lean Pull Replenishment) method is a compromise between the ideal of one-piece flow and typical large-batch “push” business models (Morgan and Liker, 2006). A Kanban system is a tool for achieving just-in-time delivery. It operates on the principle that each operation in a production line draws exactly the quantity and type of components it requires, at precisely the correct moment. A Kanban card is utilized as the mechanism. According to (Piercy and Rich, 2015) , the benefits of Kanban in lean and environmental sustainability include assisting the company in regularizing system costs and reducing material waste as a result of using Kanban. Kanban is based on the idea that material will not be created or moved until a client requests it. Most businesses have created different strategies and ways to make their production processes more efficient and successful in order to attain manufacturing excellence today. Most Japanese firms adopt the Kanban method because it reduces inventory stock levels and lowering overhead costs by removing excessive production, establishing flexible workspace, reducing waste and scrap, cutting waiting times and logistical costs, and lowering waste and trash (Gupta et al., 1999).

8) Pull Approach – Just-in-Time Practice

According to JIT delivery of materials, small lot production, pulling materials across the manufacturing system, and small lot producing (Rothenberg et al., 2001), will lower the likelihood of large batches of defective materials and reduce in-process waste. The pull technique, according to The pull technique, according to (Vinodh et al., 2011), reduces floor space utilization, lowers work in process, and eliminates possible waste from damaged goods. The identification and removal of undesirable entities, as well as correct chemical management, can make wastes, especially environmental wastes, apparent on the shop floor (EPA, 2003). Process improvement skills of key production function practices, such as process and equipment practices and manufacturing planning control, are predicted to have a beneficial influence on the businesses' environmental performance. Process improvement skills, according to (King and Lenox, 2001) , are related with decreased pollutant creation, which can help to enhance environmental performance. Scholars have argued that increasing the amount of waste reduction and resource utilization in the manufacturing process will minimize emissions and onsite treatment ((Hart, 1997, King and Lenox, 2001). Pull and visual control are core production function practices that result in reduced product damage and degradation and encourage correct chemical handling, which can enhance environmental performance (EPA, 2003, Fliedner, 2008, Vinodh et al., 2011).

Just-in-time (JIT) is a pull system that entails producing the required units in the required quantities at the required time. By establishing two essential concepts: just-in-time and automation, a continuous flow of production across the firm or supply chain, or adaptability to variations in demand in numbers and variety, is produced. The TPS is built on the foundations of these two ideas (Monden, 1998). It is a lean principle reaction to a pull system. Customers initiate demand, which is what is required in this situation. The benefits of the pull system in LM, according to (Piercy and Rich, 2015), are to regularize the system, which lowers production costs and reduces material waste for environmental sustainability. Pull systems enhance both LM and environmental sustainability by lowering in-process and finished-goods inventories, avoiding the possibility of damaged waste, spoilt, or degraded goods, and requiring less floor space (Fliedner, 2008). There are two distinct properties of pull systems. First, because they have a set inventory, they must calculate the cycle stock, as well as the buffer and safety stocks. Second, when product is withdrawn, they are activated, signaling the upstream process to start producing—no signal, no production. Overall, JIT in the organization must be completely accepted with a "JIT support system," which includes a three-function cultural transformation. JIT material supply and product manufacturing come first, followed by JIT issue solving and JIT maintenance (Wilson, 2010). According to www.isiworld.net 's Lean Value Assessment (LSI Tool), the pull system has six features.

1. The objective and actual hourly output, as well as the shift's production needs and timing, have been clearly presented in each Manufacturing cell, line, or process.
2. The ideas and implementation of shop floor material pull systems have been taught to all production managers and supervisors.
3. As parts or materials are used, material follow or plant concept is based on the "make one move one" concept or is reliant on particular pull signals from subsequent work stations via Kanban, etc.
4. Material is pulled from upstream processes by downstream processes. Production schedules in the upstream are influenced by demand in the downstream.

5. Only one manufacturing schedule at the pacemaker process can be changed., manufacturing lines/cells may respond to variations in client demand.
6. Production supervisors are not driven to create more components than are required by the succeeding procedure.

Heijunka (production leveling), Continuous Flow, Takt time, Minimum lot size (batch size), and Store, Buffer, and Safety stocks will be discussed as essential JIT practices to support the pull principle.

Tables 14 The most essential JIT approaches in Lean Environmental Principles

	Lean Environmental Sustainability Principles		
JIT (Pull approached)	**1.Waste Reduction**	**2. Process centered Focus**	**3. High level of people involvement and participation**
1.Heijunka (Production Leveling)	Contributes to inventory reduction (Press, 2006)	Everyone is putting in the same amount of effort to meet the customer's needs. No one is overloaded, and no one is waiting, therefore everyone is working in a BALANCED manner. (Rother and Harris, 2001)	One of the most essential factors is how operators allocate work among themselves in order to ensure that the actual loading procedure is exact. (Press, 2006) (Rother and Harris 2001) **.**
2.Continuous Flow	With no stoppages, scrap, or backflows, a product progresses from from design to launch, order to delivery, and raw materials into consumer hands" (Womack and Jones, 1997)	The flow method is used to synchronize processes. (Womack and Jones, 1997)	A intuitive belief that tasks should be organized by kind so that they may be performed and handled more efficiently. (Womack and Jones, 1997)
3.Takt time	Production stability—by controlling overproduction, the system is stabilized, and inventories and start-ups are avoided. (Weiss and Johnston, 2012)	To fulfill consumer demand, A particular pace of completion is required for the final product. Every takt time, a whole product, assembly, or machine is created. (Weiss and Johnston, 2012)	Employees labor without taking any breaks or attending meetings. (Weiss and Johnston, 2012)

4.Minimum lot size (batch size)	Reduces system variability and streamlines production, while also improving quality, simplifying scheduling, reducing inventory, enabling Kanban, and encouraging continuous improvement. (Kilpatrick, 2003)	Reduces the amount of inventory that is still being worked on (WIP). Not only does this save money on inventory, but it also reduces manufacturing lead time or cycle time, which is roughly proportionate to the quantity of WIP. (Kilpatrick, 2003)	Employees should strive for continual improvement in order to keep batch sizes as small as feasible. (Kilpatrick, 2003)
5.Store, Buffer, Safety Stocks	Reduce the high production and management costs. (Wilson, 2010)	Designed to handle typical supply and demand changes, allowing the manufacturing process to remain at takt and as steady as possible. (Wilson, 2010)	The ideas and application of shop floor material pull systems have been taught to all production managers and supervisors. www.isiworld.net
6.Standard Inventory management	Using FIFO inventory management, a withdrawal from the buffer stock denotes a rare occurrence that necessitates formal corrective action. (Wilson, 2010)	Reduce variance in the manufacturing process to a bare minimum, resulting in lower inventory without compromising customer service. (Wilson, 2010)	The ideas and application of shop floor material pull systems have been taught to all production managers and supervisors. www.isiworld.net
7.Point of use storage (POUS)	Reduce non-value activities like movement and transportation. Reduce non-value activities' waste and save money. (Kilpatrick, 2003) (Alukal, 2003)	It is based on the 5s method and transparency. (Kilpatrick, 2003)	Employees do 5s and provide openness. (Kilpatrick, 2003)

8) Balanced operations (heijunka) or production leveling

Production leveling is implemented for a variety of reasons (heijunka). Heijunka transforms unpredictably unequal customer pull into a consistent production process. To stabilize the value flow manufacturing process, it is usually utilized in conjunction with other important Lean concepts. Heijunka is a fundamental idea that aids in the stabilization of industrial processes. It's described as "the equally distributed production volume and mix across time" (Reyner and Fleming, 2004). The concept is that everyone does the same amount of effort in order to meet the customer's needs.

Variation is' smoothed,' with no one overloaded or waiting, resulting in everyone operating in a BALANCED manner. Heijunka is the sequencing of orders in a repeated pattern of production, aiming at smoothing day-to-day fluctuation in total order, according to (Press, 2006). It is just as essential as Kanban and Kaizen since it helps to reduce inventory and make better use of manpower. Because it is a more sophisticated notion of LM, it is not relevant in every scenario. We've seen heijunka work best when you have a providing resource that's responsible for manufacturing many items for numerous customers—high mix, low volume. The operator balance chart (OBC) helps establish continuous flow in a multistep, metaoperator process by distributing operator work parts in proportion to takt time, making the actual loading process fairly accurate so the entire team can debate the issue with facts. (Also known as a yamazumi board or an operator loading diagram) (Rother and Harris, 2001).

9) Continuous Flow

During the whole manufacturing process, the notion that once begun a product continues to move with value added work is conducted. According to Womack and Jones (1996), "Progressive delivery of the project along the value stream so that a product proceeds from design to launch, order to delivery, and raw materials into the hands of the consumer without stoppages, scrap, or backflows." This method is based on the common sense belief that tasks should be classified by kind in order to be performed more effectively and handled more conveniently. Furthermore, it appears to be common sense to conduct similar operations in batches to get jobs done effectively within departments (Womack et al., 2003). The lean enterprise carries the essential principles of JIT and level scheduling all the way to their logical conclusion by placing items into continuous flow wherever feasible to get produced goods to flow. Finally, process synchronization is referred to as flow method.

10) Takt time

What if you could eliminate the guesswork from developing your business processes and know exactly how good you needed to get in order to get the results you wanted from the company, according to (Weiss and Johnston, 2012)? What would it imply for your business, your personal life, and everyone on staff? The "takt" approach is a basic procedure. In lean manufacturing, takt time is the rate at which a finished product must be created to meet customer demand. Because a buyer buys a finished product every five minutes, a company's takt time of five minutes means that an entire goods, assembly, or machine is produced off the line every five minutes. As a result, takt time refers to the maximum amount of time it takes to create a product in order to fulfill customer demand. Takt time is calculated by dividing the available production time by the number of output units required. It's critical to note that the time available for production should reflect the complete number of hours (or units of time) spent by people, less any breaks or meetings. Takt time has a significant influence on production stability: it stabilizes the system and reduces inventory buildups, beginning with overproduction control. (Weiss and Johnston, 2012).

11) Minimum lot sizes (batch size)

According to (Wong et al., 2009), effective schedules decrease work in progress, stocks, and improve the firm's capacity to fulfill client demands by reducing work in progress, reducing inventories, and increasing the firm's capacity to meet client needs through small lot sizes. Appropriate scheduling approaches aid in the efficient use of resources. Small lot sizes also help in the removal of production line imbalances, resulting in a smoother production flow. This is a method of guaranteeing an orderly flow of goods through the use of pull techniques such lot size reduction. Small batch sizes (lot sizes) reduce system volatility and guarantee that production runs smoothly. Quality has been enhanced, scheduling has been streamlined, inventory has been decreased, Kanban has been used, and continuous improvement has been promoted. Prior to the introduction of lean manufacturing, businesses relied on large batch sizes were used to maximize equipment use, thinking that changeover times were “fixed” but could not be shortened.. Batch size reduction in LM, according to Kilpatrick (2003), includes creating components in response to client demand, with the ideal batch size being ONE. Because a batch size of one is not always achievable, the goal is to strive for continuous improvement in order to reduce the batch size to the smallest size practicable. The amount of work-in-process inventory is reduced by reducing batch sizes (WIP). This not only saves money on stock, but it also reduces production cycle time, which is usually proportionate to the amount of WIP on stock. Smaller batch sizes reduce the total manufacturing cycle, allowing businesses to produce items faster (with shorter lead times) and charge consumers sooner (for improved cash flow). Shorter manufacturing cycles improve inventory turns and allow the company to operate at lower margins, allowing for price cuts that increase sales and market share (Kilpatrick, 2003). Furthermore, due of the short lead time, if existing production is delayed, delaying the request from the new customer, it is discovered within one day, allowing for some remediation. If there is a long lead time, the problem might take up to a week to develop. Another type of flexibility seen in a short-lead-time production system is the ability to respond to anomalies more quickly (Wilson, 2010).

12) Store (Cycle) / Buffer / Safety Stocks

To reduce the high cost of creating and keeping inventory, several companies utilized Kanban and cut inventories as part of the JIT concept in LM. Inventory control is also an important aspect of JIT implementation. They realized that nearly everything had to be rushed, that they had to work a lot of overtime, and that they were still missing delivery deadlines on a regular basis. Others came upon the worst-case scenario. They not only missed shipments, but their production rates plummeted as stocks were depleted. As a result of these erroneous attempts, several firms lost their competitiveness and even went out of business. The concept and application of shop floor material pull systems have been taught to all production managers and supervisors. www.isiworld.net. According to Lonnie, the three types of important inventories in LM are the cycle, buffer, and safety stocks (Wilson, 2010). Cycle stock is necessary to guarantee that regular collection deliveries are performed, whilst buffer stocks and safety stocks will handle demand variations and internal supply changes, respectively. We'll be able to meet demand while maintaining a low inventory level. These stocks are designed to accommodate frequent supply and demand variations, ensuring that the manufacturing process remains on takt and as consistent as feasible.

This is where all sorts of stocks are defined.

- Cycle stocks: this is the quantity of inventory that a company needs on hand to fulfill routine customer demand pickups, also known as stores.
- Buffer stocks: This is the extra inventory volume kept above the cycle stock's inventory volume to account for external changes, and it is calculated using historical data on these external causes' swings.
- Safety stocks: this refers to the inventory that is kept in addition to the cycle and buffer stocks. It's utilized to account for variations in storeroom supplies from inside the firm.

13) Standard inventory management

As previously noted in the Store (Cycle) / Buffer / Safety Stocks section, some companies utilized Kanban and cut inventories to minimize the high cost of producing and managing inventory. Apart from the three categories of stocks described above, the following three components of lean inventory management may be discovered. (Wilson, 2010) p.55).

(i) The first-in, first-out (FIFO) approach of inventory management is a lean methodology. Stock rotation becomes tough when each component number has three types of stock.

(ii) When goods is taken from the buffer or safety stock, it is regarded an unusual event that requires official action.

(iii) Safety and buffer stock Kanban cards are typically a different color than cycle stock inventories. The safety stock Kanban should be yellow, and the buffer should be orange. Occasionally, a red Kanban is used to signal an emergency issue.

Furthermore, in a lean system with somewhat steady demand, the company will have ample time to create all of them in one cell. Others will be referred to as strangers, while others will be referred to as A models or runners. As a result, it may be more cost-effective to produce the runners on a make-to-stock basis while the strangers are made-to-order. As a result, they only have bicycles for runners on hand (Wilson, 2010). The concept and application of shop floor supply pull systems and lean inventory management have been taught to all manufacturing managers and supervisors. http://www.isiworld.net The reduction in inventory is part of the company's broader lean strategy. If inventory reductions are to be achieved, it is important to realize that inventory is created in large part due to variation in the production system. As a result, we'd prefer to limit that variation to a minimal minimum, allowing us to save inventory while maintaining excellent customer service. As a consequence, in its whole, the kanban technique is one of the most successful.

14) Point of use storage (POUS)

Materials, components, tools, information standards, and procedures should all be kept and stored in the most accessible position possible. This technique will help reduce non-value tasks like mobility and transportation (Kilpatrick, 2003, Alukal, 2003). POUS would not work without excellent housekeeping, thus it is built on 5s and transparency.

15) Supplier relationships

Importantly, the success of the lean manufacturing system is strongly reliant on supply chain integration and sharing the benefits of reciprocal performance improvement investment between the customer and the supplier. Environmental performance is akin to lean manufacturing principles. Just-in-time, quality systems, work teams, cellular manufacturing, and supplier management are all examples of lean production (Shah and Ward, 2003). The lean manufacturing concept emphasizes minimizing seven types of waste and treating customers, workers, and suppliers with respect (Womack et al., 1990, Womack and Jones, 1997, Monden, 1998). Typically, businesses bear essentially no legal liability for their suppliers' environmental activities. Customer companies may be accountable for the items or services they have acquired, but they are not legally accountable for their supplier's other acts (Simpson and Power, 2005a). There is evidence to imply that the buying function is aware of the increasing relevance of environmental management practices among suppliers to the firm (Lamming and Hampson, 1996). However, the buying function has the challenge of monitoring and developing suppliers in environmental management practices without incurring significant transaction costs or interrupting production flow. Theory and research regarding the impact of a supplier's environmental management activity on the supply relationship are less established. Other works, on the other hand, have stated shaky connections (Lamming and Hampson, 1996, Florida, 1996, Geffen et al., 2000). In process improvement, there is a correlation between the structure of the supply relationship and the degree of performance of the provider, according to the literature (MacDuffie and Helper, 1997, Wu and Management, 2003, Kotabe et al., 2003). Researchers in a variety of academic fields have been looking into the possibility for parallelism between environmental management and supply chain management over the past five years. An rising number of academic publications have been published in these fields, with the goal of developing theory in accordance with corporate requirements for speedier, more flexible, efficient, and socially responsible supply chains. The customer-supplier connection is emphasized as a key facilitator for the long-term development of production systems and supplier capabilities (Lamming and Hampson, 1996, Das et al., 2000, Krause et al., 2000). The susceptibility of lean manufacturing is not confined to internal sources of unpredictability, but also to external sources of unpredictability (Wong et al., 2009). By decreasing supply unpredictability, supply management in lean manufacturing aims to eliminate waste of extra inventory or surplus capacity. The environmental performance of suppliers is becoming increasingly important to the supply function (Hall, 2000, Jones et al., 1998, Faruk et al., 2001, Sarkis, 2003). A high degree of environmental performance attained by one company may be undermined by its suppliers' poor environmental management (Faruk et al., 2001). Environmental management might potentially be an undiscovered source of cost savings in the supply chain by making better use of natural resources (Hart and Ahuja, 1996, Florida, 1996). There are various advantages to a client that chooses to include environmental considerations in the performance specifications of its suppliers. Reduced hazards connected with chemical management and storage, more successfully satisfying corporate social responsibility objectives, production system benefits through enhanced processes, and chances for innovation are just a few examples. It improves the customer's ability to respond more quickly to supplier environmental performance concerns, thereby protecting the firm's investments and image. An interdisciplinary relationship between the extensive extent of both the supply chain management and environmental management literature is necessary in order to create theory in supplier environmental performance management. Simpson and Power (2005) (Simpson and Power, 2005a)

Supplier Relationship Benefits in LM Environment Sustainability

1. Eliminating surplus inventory waste
2. Waste reduction through fewer flaws, less scrap, and lower energy consumption
3. Risks related with chemical handling and storage are reduced.
4. Respond more quickly to supplier environmental performance concerns.

According to (Martínez-Jurado and Moyano-Fuentes, 2014), the concepts of Lean and Green or Environmental discussion under the study framed are corresponding and are administered by three principles that find the relationship of benefit of supplier relationship in Lean Environment Sustainability and these three principles.

Tables 15 In the field of supplier relationships, lean environmental sustainability concepts and practices are used.

Benefit of supplier relationship in Lean Environment Sustainability	Lean Environment Sustainability Practices in the area of Supplier Relationship	LM and Environment Sustainability Principle
1. Eliminating surplus inventory waste	1. Participation of suppliers in the creation of new products	Reduction of waste
2. Waste reduction through fewer flaws, less scrap, and lower energy consumption	1. The use of new materials and related procedures. 2. A collaborative approach to issue resolution 3. Programs of collaborative quality	Reduction of waste

	improvement with suppliers	
3. Risks related with chemical handling and storage are reduced.	1.Collaborative efforts to improve product design and process efficiency	Focused on the Process
4. React more quickly to supplier environmental performance concerns.	1. Approach to developing a lean environment that is sustainable with existing suppliers	Involvement and participation of a large number of people.
	2. Appropriate supplier performance monitoring	
	3. Provide suppliers with a financial incentive	

15) Participation of suppliers in the creation of new products

The elimination of excess inventory waste is a benefit of suppliers' engagement in new product development. As a result, controlling unpredictability with suppliers lowers inventory levels. Supply chain management methods such as a small number of essential suppliers, long-term contracts, JIT delivery by suppliers, and giving supplier development in the manufacturing process for future improvement can help to control this unpredictability (Shah and Ward, 2003). The concept of supply management emphasizes the importance of establishing closer and long-term relationships with suppliers, not only at the logistical level, such as JIT delivery, but also at the strategic and technological level, such as participation in new product development, in order to avoid excess inventory (Panizzolo, 1998, Piercy and Rich, 2015, Fliedner, 2008). The adaption of environmentally aware production is facilitated by close relationships with suppliers (Piercy and Rich, 2015, Fliedner, 2008). For example, the emphasis on just-in-time delivery necessitates inventory and waste reduction. Furthermore, including suppliers in new product development allows for the creation of more efficient and environmentally friendly processes and products (Florida, 1996). Another advantage of supplier participation in new product development is the decrease of waste due to fewer mistakes, scrap, and energy use. Supplier relationship strategies can open up a lot of doors for increased joint productivity and environmental performance. The environmental advantages of lean manufacturing are amplified by lean supplier relationship techniques, which reduce waste through fewer defects, less scrap, and lower energy use. (Fliedner, 2008, Piercy and Rich, 2015, Panizzolo, 1998). In the literature on supply chain management, customer-supplier interactions are becoming increasingly essential as a factor in improving performance and gaining a competitive edge in the supply chain. Suppliers can have a direct influence on a customer's key cost, quality, technology, delivery, flexibility, and profit aspects. In order to achieve supply chain scale cost savings, improvements in quality and service, and the expanded inclusion of environmental aims into goods, businesses are increasingly looking outside of the firm and to the performance of their suppliers. The manufacturing function is responsible for a large amount of the supply function's costs. The manufacturing function also plays a key role in environmental management activities such as waste reduction, energy efficiency, and innovation.

16) Implementation of cutting-edge materials and procedures with suppliers

Closer supplier relationships give companies with more relevant experience on the supplier side, which may help enhance environmental performance by using novel materials and procedures.(Yang et al., 2011b, Yang et al., 2011a)

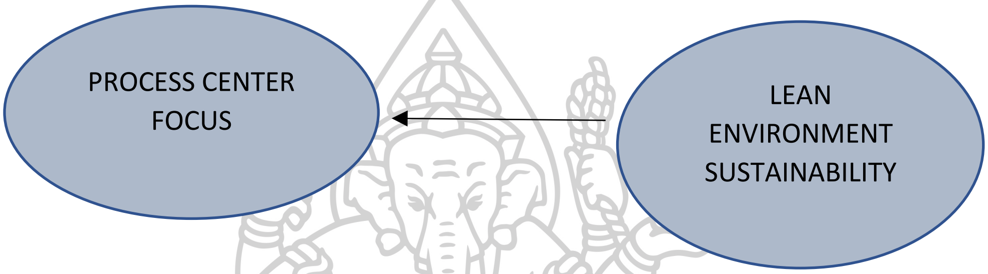
17) A collaborative problem-solving strategy with suppliers

A well-developed and routine supply relationship may inspire a collaborative approach to issue resolution, resulting in cost savings, improved quality, and the introduction of new and essential expertise. (Lamming and Hampson, 1996, Krause et al., 2000, Dyer and Nobeoka, 2000).

18) Resulting in collaborative quality improvement initiatives with suppliers

Recent papers in the environmental management literature suggest that the supply connection can lead to joint projects, such as (www. isiworld.net , (Lamming and Hampson, 1996, Florida, 1996, Geffen et al., 2000, Hall, 2000, Panizzolo, 1998, Piercy and Rich, 2015, Fliedner, 2008).1) Waste reduction, 2) Environmental innovation at the interface, 3) Cost-effective environmental solutions, 4) Rapid creation and acceptance of environmental technology innovation, and 5) Enables customer firms to better understand the environmental consequences of their supply chains.

2. Principle of Process Center Focus



Figures 5 The principle of lean environment sustainability is Process Centered Focus.

The process center focuses on fifteen lean environment sustainability strategies, including: 1) Kaizen, 2) 5S, 3) Reduce the amount of time you spend on tasks, 4) Manufacturing of cells, 5) Planning ahead of time, 6) TPM, 7) Kanban practice, 8) Heijunka, 9) Takt time, 10) Keep a buffer and a safety supply on hand., 11) Flowing indefinitely, 12) Lot Size Requirement, 13) Inventory that is standard,14) POUS, and 15) Suppliers are involved in the development of new products., (see Table 16)

Tables 16 Principle of Process Center Focus

No.	Principle	Lean Environment Practices
1.	Process Center Focus	Kaizen on process improve in a short amount of time.
2.	Process Center Focus	5S aids in the standardization of work on the shop floor.
3.	Process Center Focus	Setting up a timer aids in the conversion process.
4.	Process Center Focus	Processing of cellular manufacturing is efficient.
5.	Process Center Focus	Complexity is reduced by planning ahead of time.

6.	Process Center Focus	TPM is an objective for continuous improvement.
7.	Process Center Focus	Kanban cards are used to retrieve material.
8.	Process Center Focus	Working together, Heijunka maintains a sense of equilibrium
9.	Process Center Focus	Focus on takt time in the production line.
10.	Process Center Focus	Production is support by a buffer store and safety stock.
11.	Process Center Focus	Flow synchronization on a continuous basis.
12.	Process Center Focus	System fluctuation, a minimum lot size is required.
13.	Process Center Focus	Variation is reduced by using standard inventory.
14.	Process Center Focus	POUS with correct transparency and 5S.
15.	Process Center Focus	Product design is being improved by the supplier.

1) Kaizen in process centered focus principle

Kaizen is a Japanese concept that focuses on reducing waste, increasing productivity, and achieving long-term improvement in a company's focused operations and processes. Kaizen is based on the idea that tiny, incremental adjustments made repeatedly and consistently over time result in big overall gains. Rapid process improvement events, often known as kaizen events. The team views the process as if they were the material, data, or documentation being transferred through the system, according to (Martin and Osterling, 2007) Kaizen events employed in apply improvements value stream mapping (create flow).

2) Improve standardized work methods with 5S with a process-centered focus

The company established 5S rules to create a consistent approach and storage areas by making simple visual rules and training on maintain standards to reduce search time and avoid mistakes to assign job responsibilities. 5S stands for visual housekeeping and is the first phase in the lean process, since it helps to focus attention on the shop floor in order to develop standardized work practices that will aid in workplace control. (Filip and Marascu-Klein, 2015) (Halim et al., 2014). It stems from the concept that routines that preserve structure and order are necessary for a smooth and efficient flow of activities in a company's daily operations. The use of this strategy "cleans up" and "organizes" the workplace in its current configuration. The 5S (seiri, seiton, seiso, seiketsu, and shitsuke) technique was introduced to enhance workspaces, boost the quality of the working environment, remove or decrease errors, and maintain the industrial process performance (Filip and Marascu-Klein, 2015).

3) Set up a process-centered focus to reduce time

Reduced setup time allows a manufacturing process to transition fast and effectively from running one product to the next. From process and packaging plants to aircraft, the core principles of SMED have been employed to cut setup and turnaround time in various sorts of manufacturing, assembly, and even service sectors.(Shingo, 1996). For a business to succeed, it must be flexible and responsive to client expectations. In most cases, extra time is required for setup due to poor equipment design. The phrases continuous process improvement and SMED (single minute exchange of dies) as a lean manufacturing method come into play at this time. Not just for production enhancement, but also for equipment/die design development, "rapid changeover" is still a viable option. (Cakmakci and Karasu 2007).

4) Process-centered focus concept in cellular manufacturing

"A cell is a tiny organizational unit created to take advantage of commonalities in how people absorb information, create products, and serve customers. People and equipment needed to process families of similar items are concentrated in manufacturing cells. [Prior to cellularization, parts] Many kilometers may have been traveled to see all of the necessary equipment and manpower for their fabrication. Following reorganization, families of comparable components are manufactured together inside the physical boundaries of cells that hold most or all of the needed resources, allowing for faster material flow and information processing. Furthermore, cell operators can be cross-trained on multiple machines, participate in job rotation, and take on tasks that were previously the responsibility of supervisors and support staff, such as planning and scheduling, quality control, troubleshooting, parts ordering, interacting with customers and suppliers, and record-keeping (Reisman et al., 1997, Metternich et al., 2013).

5) Preparation for production The process-centered emphasis idea applies to planning

Pre-production planning, according to (Fliedner, 2008), is a lean method and tool for reducing the complexity of the manufacturing process ("design for manufacturability") and eliminating or streamlining process steps; environmentally sensitive processes can be targeted for getting rid and they're often time, resource, and capital-intensive, as well as less compliant. A production system is an assemblage of production subsystems that constitute the whole production flow from raw materials or components into the hands of the customer via a company's value streams (Erlach, 2005)

6-10) Pull Approach – Just-in-Time Practice

The following are some of the most essential JIT approaches for supporting the pull principle: 6) Heijunka (production leveling), 7) Continuous Flow, 8) Takt time, 9) Minimum lot size (batch size), 10) Store, Buffer, Safety stocks, 11) Standard Inventory management, and 12) Point of use storage (POUS).

Tables 17 The most significant JIT approaches in Lean Environmental Principles

Principles of Lean Environmental Sustainability

JIT (Pull approached)	**1.Waste Reduction**	**2. Process centered Focus**	**3. High people involvement and participation**
6.Heijunka (Production Leveling)	Contributes to the decrease of inventory (Press, 2006)	Everyone is putting in the same amount of effort to meet the customer's needs. No one is overworked, and no one is waiting, thus everyone is working in a BALANCED manner.(Rother and Harris, 2001)	One of the most crucial factors is how operators allocate work among themselves in order to ensure that the actual loading procedure is correct. (Press, 2006) (Rother and Harris 2001) **.**
7.Continuous Flow	With no stoppages, scrap, or backflows, a product	The flow approach is used to synchronize processes.(Womack and	A intuitive belief that tasks should be classified by kind so that they may be

	progresses from concept to launch, order to delivery, as well as raw materials into the customer's hands" (Womack and Jones, 1997)	Jones, 1997)	performed and handled more efficiently.(Womack and Jones, 1997)
8.Takt time	Production stability—by restricting overproduction, the system is stabilized, and inventories and start-ups are avoided.(Weiss and Johnston, 2012)	To fulfill client demand, a final product must be created at a certain rate. A whole product, assembly, or machine is produced off the line every takt time. (Weiss and Johnston, 2012)	Employees labor without taking any breaks or attending meetings. (Weiss and Johnston, 2012)
9.Minimum lot size (batch size)	Reduces system variability and streamlines production, while also improving quality, simplifying scheduling, reducing inventory, enabling Kanban, and encouraging continuous improvement.(Kilpatrick, 2003)	Reduces the amount of inventory that is still being worked on (WIP). Not only does this save money on inventory, but it also reduces manufacturing lead time or cycle time, which is roughly proportionate to the quantity of WIP.(Kilpatrick, 2003)	Employees should strive for continual improvement in order to keep batch sizes as small as feasible. (Kilpatrick, 2003)
10.Store, Buffer, Safety Stocks	Reduce the high production and management costs. (Wilson, 2010)	Designed to handle regular supply and demand changes, allowing the manufacturing process to remain at takt and as steady as possible(Wilson, 2010)	The concept and application of shop floor material pull systems have been taught to all production managers and supervisors. www.isiworld.net
11.Standard Inventory management	Using FIFO inventory management, a withdrawal from the buffer stock denotes a rare occurrence that necessitates formal corrective action(Wilson, 2010)	Reduce variance in the manufacturing process to a bare minimum, resulting in lower inventory without compromising customer service. (Wilson, 2010)	The concept and application of shop floor material pull systems have been taught to all production managers and supervisors. www.isiworld.net
12.Point of use storage (POUS)	Reduce non-value activities like movement and transportation. Reduce non-value activities' waste and save money. (Kilpatrick, 2003) (Alukal, 2003)	It is based on the 5s method and transparency. (Kilpatrick, 2003)	Employees do 5s and provide openness. (Kilpatrick, 2003)

13) Process-centered focus principle (TPM)

Process improvement is the emphasis of TPM activities. According to TPM, lean manufacturing appropriate speed the design efficiency of changes, allowing for the shipment of greater customer value with less attempt, while TPM tools improve the performance of the transformation process, such as dealing with the things that probably don't go as planned. (McCarthy and Rich, 2004). TPM is a continual improvement that the organization may aim for and incorporate into its daily operations. To determine how TPM affects lean manufacturing in seven areas of measurement, follow these steps:

(i) Productivity: TPM may minimize non-value-adding tasks while also increasing the contributed value per labor hour.

(ii) Quality: TPM can detect quality issues early on.

(iii) Cost: TPM can help you save money by reducing your inventory.

(iv) Delivery performance: TPM has the ability to reduce lead times and speed up conversion procedures.

(v) Security: TPM can minimize movement, clutter, and anomalous circumstances, making them more noticeable.

(vi) Morale: TPM may eliminate clutter, bring you closer to your customers, and give you a better understanding of what makes a client valuable.

(vii) Environment: TPM has little influence on 'overproduction,' as systems are designed on demands rather than theoretical batching requirements.

TPM efforts comprised the following process techniques, according to Lean Value Assessment (LSI Tool) www.isiworld.net: 1) TPM basics have been taught to maintenance team supervisors and personnel., 2) All essential safety guards are installed on the machines. When equipment breaks down or is otherwise inappropriate, safety devices are in functioning condition and equipment is promptly locked out., 3) Activity lists for preventive maintenance are displayed in work areas, and item completions are recorded over time., 4) For all production and support equipment, up-to-date and easily accessible maintenance records are stored and displayed nearby.., 5)Both maintenance and production staff have specified preventive maintenance obligations.

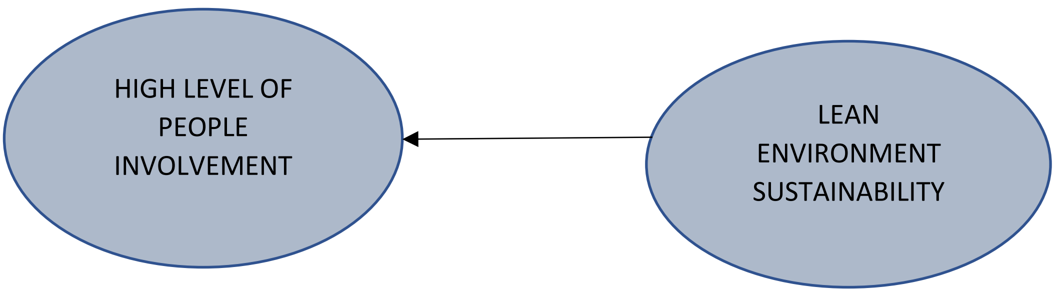
14) Kanban in process centered focus principle

Kanban is often a physical card, although it may also be utilized with various technologies. When the strategic inventory is exhausted, the downstream client sends a simple card or "Kanban" to the upstream supplier, instructing them to either replenish the bin with a particular quantity of components or return a card with precise information on the item and its location.(Kumar et al., 2012). As a result, it focuses on the complete value stream process, such as Kanban in pattern manufacturing. This form of production is frequently required in heat treat operations, paint, or other processes with precise changeover sequences (www.lean.org).

15) Joint approaches to better product design and process efficiency with suppliers

The production system is a good place to start for such study. Reciprocal benefits for both manufacturing and environmental performance are available when companies work together to improve product design and process efficiency, resulting in total waste reduction and innovation. (Simpson and Power, 2005b, Simpson and Power, 2005a).

3. High level of people involvement and participation



Figures 6 The idea of lean environment sustainability is a high level of people involvement and participation

There are sixteen lean environment sustainability techniques that have a high level of participation and involvement from people: 1) Kaizen., 2) 5S., 3) Reduce the amount of time you spend on tasks., 4) Manufacturing of cells., 5) Planning ahead of time, 6) TPM, 7) Kanban practice, 8) Heijunka., 9) Takt time., 10) Continuous flow., 11) Training., 12) POUS., 13) Continuous flow, 14) Existing supplier response environment., 15) Provide a financial incentive to the provider., and 16) Long-term plan for evaluating supplier performance (see Table 18)

Tables 18 High level of people involvement and participation principle

No.	Principle	Lean Environment Practices
1.	High People Involvement	Kaizen calls participation from the entire team.
2.	High People Involvement	Staff members contribute new ideas to 5S.
3.	High People Involvement	SMED need personnel.
4.	High People Involvement	People in cellular manufacturing are involved.
5.	High People Involvement	People's engagement in pre-production planning
6.	High People Involvement	TPM increased staff productivity.
7.	High People Involvement	Operators are told to do using Kanban rules.
8.	High People Involvement	The heijuka operator is a crucial component.
9.	High People Involvement	The working hours shown in Takt time.
10.	High People Involvement	Worker practice that is always improving
11.	High People Involvement	Worker practice with a small batch size
12.	High People Involvement	Employees are involved in POUS.
13.	High People Involvement	Workers that operate in a continuous flow are more productive.
14.	High People Involvement	Environment for supplier responsive available

15.	High People Involvement	Provide a financial incentive to the provider if he or she meets the aim.
16.	High People Involvement	Long-term plan for evaluating supplier

1) Kaizen entails a high level of participation and involvement from the general public

Kaizen is based on the idea that tiny, incremental adjustments made repeatedly and consistently over time result in big overall gains. Kaizen is sometimes referred to as the "building block" of all Lean production strategies. Kaizen's amazing accomplishments are frequently the consequence of:

- Kaizen's emphasis on moving quickly from planning to implementation;
- Kaizen's emphasis on making continuous progress rather than waiting for the perfect solution;
- Kaizen's emphasis on worker participation and teamwork;
- Kaizen's emphasis on addressing root causes of problems; and
- Kaizen's emphasis on process improvement from a systems perspective.

In regards to (Piercy and Rich, 2015) Kaizen provides mutual advantages to LM in terms of engaging employees, finding solutions to problems, and long-term advantages for engaged employees and a better workplace.

2) 5S in which there is a high level of engagement and involvement from the people

Benefits of 5s include allowing employees the opportunity to contribute creatively, as well as fostering a culture of continual growth and team spirit. (Kilpatrick, 2003) It is frequently used as the beginning point for shop-floor change. Sort, Set In Order, Shine, Standardize, and Sustain are the five pillars of the 5S process for organizing, cleaning, developing, and maintaining a productive work environment. By using tools signs and posters, newsletters, pocket manuals, team and management check-ins, performance reviews, and department tours, all 5S activities are monitored, evaluated, and continuously improved, resulting in a deep cleaning, eliminating sources of dirt, and simplifying the cleaning process, as well as daily follow-up cleaning.(Filip and Marascu-Klein, 2015)

3) Reduce the amount of time you spend on each task. People involvement and engagement at a high level- Involve manpower

According to Dave (Dave and Sohani, 2012), SMED may be used in conjunction with other lean tools to enhance not just mechanical processes but also procedural and organizational processes, as well as save personnel, which is one of the most valuable resources in the company. Each of these seven main motion elements has its own set of codes and time values. These fundamental elements, as well as the cycle for the time values of the components, may simply describe an operation. This procedure may be readily calculated by just adding the numbers together. With a stopwatch and/or videotape, each setup operation is timed and documented for employees. (Wisconsin Manufacturing Extension Partnership, (Cakmakci and Karasu, 2007) MTM-UAS)

4) Cellular Manufacturing entails a high level of engagement and involvement from the general public

Cells are built in a workplace to facilitate flow, according to (Hall, 1987, Metternich et al., 2013) This is performed by gathering together processes (or equipment, or people) engaged in a product's natural flow processing sequence and grouping them close together, separate from other groups. A cell is the name for this collection. These cells are used in manufacturing to enhance a variety of aspects by permitting one-piece flow. The manufacturing of a metallic case part that arrives at the plant in separate parts from the vendor and requires assembly is an example of one-piece flow. The components would first be transferred from storage to the cell, where they would be welded together, polished, coated, and lastly packed. All of these procedures would be accomplished in a single cell in order to reduce non-value-added processes/steps like the time it takes to move materials between phases. The U-shape (excellent for communication and efficient worker mobility), the straight line, and the L-shape are all frequent single cell forms. The number of workers in these formations is determined by demand and may be adjusted to boost or decrease output.

For example, if a cell typically holds two employees and demand doubles, the cell should be filled with four workers. Similarly, if demand falls by half, the cell will be occupied by one worker. Because cells include a range of different equipment, every employee must be able to do several operations.

5) Pre-production planning with a high degree of participation and involvement from the public

Pre-production planning is one of the lean methods and tools with associated environmental benefits based on the principle of high levels of people involvement and participation. People, equipment, and procedures are arranged into production systems to complete a company's manufacturing operations (Cochran et al., 2000, Matt, 2008, Groover, 2001). Manufacturing that eliminates waste and decreases material and energy needs cannot be effective without the engagement of humans.

6) TPM has a high level of engagement and involvement from the general public

The operator assumes main responsibility for his or her plant, maximizing the operator's abilities and knowledge of his or her plant to maximize operating effectiveness: As a result, the operator is alerted to early indicators of wear, misalignments, leaks, misdirected chips, or loose pieces. according to (Eti et al., 2006) TPM tool results of this optimized performance of employees. Technicians making required changes to eliminate loses to plant failures or sub-optimal performance, as well as creating a clean-up and predictive maintenance plan to extend the plant's life-span and maximize uptime, and improving overall plant productivity with cross-functional teams of operators, maintenance personnel, technologists, and managers. According to (Chan et al., 2005), they looked into a company that made semi-conductive items. They claimed that development in the utilization of equipment had been accomplished as a result of TPM applications. They discovered that workers' knowledge and abilities had improved, and that their motivation to work had improved.

7) Kanban has a high level of engagement and involvement from the people

Because the operators utilize visual signals to decide how much they run and when they stop or change over, Kanban scheduling necessitates a high level of people involvement and engagement. The Kanban rules also instruct the operators on what to do in the event of an issue and who to contact in the event of an issue. It's a visual indication that helps managers and supervisors to quickly see the line's scheduling status (Kilpatrick, 2003). A returned Kanban card put on the board in the shadow area in lot making with a batch board Kanban shows inventory has been consumed in the market; unreturned cards reflect inventory still in the market. When predetermined trigger points are reached, the production operator is alerted to begin producing goods in order to refill the market's supply. If many trigger points are achieved at the same time, production must develop some guidelines for what to create first (because the pattern or sequence is not defined in this case) and where to make it. Otherwise, supervisors will make decisions based on the facts supplied (www.lean.org).

8-13) Just in time practice – Pull Approach

The following are some of the most essential JIT approaches for supporting the pull principle: 8) Heijunka (production leveling), 9) Continuous Flow, 10) Takt time, 11) Minimum lot size (batch size), 12) Store, Buffer, Safety stocks, 13) Standard Inventory management, and 14) Point of use storage (POUS)

Tables 19 The important techniques of JIT practice in Lean Environmental Principles

	Lean Environmental Sustainability Principles		
JIT (Pull approached)	**1.Waste Reduction**	**2. Process centered Focus**	**3. High level of people involvement and participation**
8.Heijunka (Production Leveling)	Contributes to the decrease of inventory (Press, 2006)	Everyone is putting in the same amount of effort to meet the customer's needs. No one is overworked, and no one is waiting, thus everyone is working in a BALANCED manner.(Rother and Harris, 2001)	One of the most crucial factors is how operators allocate work among themselves in order to ensure that the actual loading procedure is correct (Press, 2006) (Rother and Harris 2001) .

9.Continuous Flow	Tasks are completed in a sequential manner along the value stream, ensuring that a product moves smoothly from design to launch, order to delivery, and raw materials into the hands of the consumer, with no delays, scrap, or backflows.(Womack and Jones, 1997)	The flow approach is used to synchronize processes.(Womack and Jones, 1997)	A intuitive belief that tasks should be classified by kind so that they may be performed and handled more efficiently.(Womack and Jones, 1997)
10.Takt time	Production stability—by restricting overproduction, the system is stabilized, and inventories and start-ups are avoided. (Weiss and Johnston, 2012)	To fulfill client demand, a final product must be created at a certain rate. A whole product, assembly, or machine is produced off the line every takt time. (Weiss and Johnston, 2012)	Employees work after any breaks or meetings have been taken. (Weiss and Johnston, 2012)
11.Minimum lot size (batch size)	Improves quality, simplifies scheduling, reduces inventory, enables Kanban, and encourages continuous improvement by reducing unpredictability in the system..(Kilpatrick, 2003)	Reduces the amount of inventory that is still being worked on (WIP). Not only does this save money on inventory, but it also reduces manufacturing lead time or cycle time, which is roughly proportionate to the quantity of WIP. (Kilpatrick, 2003)	Employees should strive for continual improvement in order to keep batch sizes as small as feasible. (Kilpatrick, 2003)
12.Store, Buffer, Safety Stocks	Reduce the high production and management costs. (Wilson, 2010)	Designed to handle regular supply and demand changes, allowing the manufacturing process to remain at takt and as steady as possible. (Wilson, 2010)	The concept and application of shop floor material pull systems have been taught to all production managers and supervisors. www.isiworld.net
13.Point of use storage (POUS)	Reduce non-value activities like movement and transportation. Reduce non-value activities' waste and save money. (Kilpatrick, 2003) (Alukal, 2003)	It is based on the 5s method and transparency. (Kilpatrick, 2003)	Employees do 5s and provide openness. (Kilpatrick, 2003)

14) Approach to developing a lean environment that is sustainable with existing suppliers

Lean manufacturing necessitates a customer-supplier relationship that fosters strong learning motivation and trust. The ideal technique of the lean client to assure lean supply is to improve the lean capabilities of current suppliers. Rather of recruiting new, already lean suppliers, the corporation achieves more environmental advantages by teaching lean to current local suppliers (Fliedner, 2008, Lamming and Hampson, 1996, Halloran et al., 1997, Piercy and Rich, 2015). High levels of information exchange, quick supplier performance gains, and minimal transaction costs define well-developed lean supply arrangements (Lamming and Hampson, 1996, Halloran et al., 1997). The easiest strategy to get suppliers to respond quickly to challenges of environmental performance is to use a lean environment sustainability strategy to build with current suppliers.

15) Suppliers should be rewarded

Such supply circumstances may offer the impetus that client firms require to lawfully overcome the organizational boundary and become active in their suppliers' environmental activities on a supply chain scale. the goal (Lamming, 1993, Dyer, 1997, MacDuffie and Helper, 1997, Liker and Wu, 2000, Kotabe et al., 2003, Klassen, 2000, Rothenberg et al., 2001).

16) Appropriate supplier performance monitoring

Suppliers participate in the company's continuous improvement activities, sharing a high degree of information and achieving quick performance improvements with low transaction costs. (www.isiworld.net, Lamming and Hampson, 1996, Halloran et al., 1997, Piercy and Lamming, 1993; Dyer, 1997, Piercy and Rich 2015). However, the significance of cost, quality, and delivery dominates supply relationships. When compared to the requirements produced by any of these three key supply demands, the environment is rarely a crucial task. Without the protection of adequate safeguards and monitoring, supplier environmental performance is likely to be extremely vulnerable to opportunism. However, the importance of The company has effectively met with suppliers for their performance on environment corporate benefits to the manufacturing system through improved overall waste reduction and innovation are achieved through the product design process with regular monitoring is dominated by supply relationships. (Simpson and Power, 2005a, Piercy and Rich, 2015). Long-term development strategies for assessing a supplier's operations and performance in order to improve a supplier's technical, quality, delivery, and cost capabilities, as well as responding to service complaints, creating competition among suppliers, and working directly with suppliers through training, education, and other means to achieve the environmental practices target (Lamming, 1993, Dyer, 1997, MacDuffie and Helper, 1997, Liker and Wu, 2000, Kotabe et al., 2003, Klassen, 2000,Rothenberg et al., 2001).

2.15 Lean Social Sustainability and Lean Manufacturing

2.15.1 Principles of Lean Social Sustainability

One of the sustainability triple bottom lines is the organization's social sustainability performance. The goal of social sustainability is to treat your employees fairly. This is also known as human capital, and it refers to a company's fair and helpful business practices toward its employees as well as the community and region in which it operates. According to (Savitz & Weber, 2006), the balanced scorecard captures in numbers labor practices, community impacts, human rights, and product responsibility under social outcome performance. Workforce issues concern how a company handles its employees. There were four sub-dimensions identified: (Piercy and Rich, 2015). 1. Workplace operational issues (providing a safe working environment with good working conditions), 2. Compensation (fair wages and payment), diversity issues (non-discrimination in hiring) and 3. Union relations (recognition) (Panapanaan et al., 2003) (Meijer et al., 2005) (Wagner, 2008) et al., 2008).

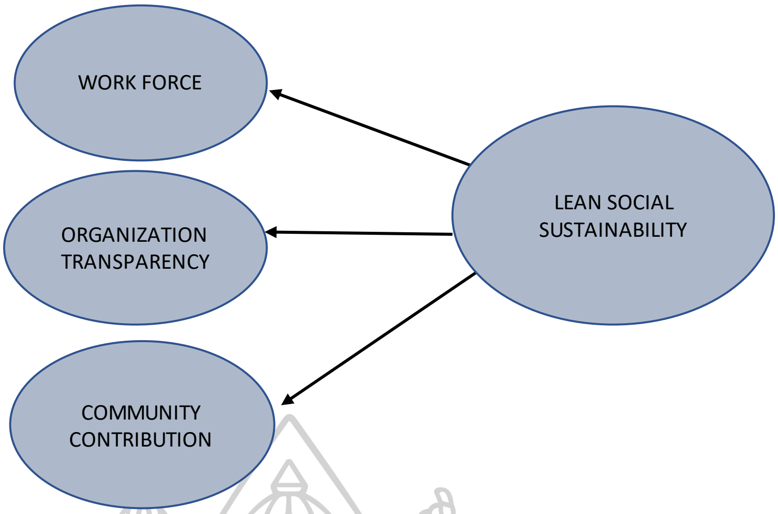
A favorable association between worker engagement and environmental performance has already been discovered in research (Florida, 1996) (Kitazawa et al., 2000, Sarkis, 2003). Lean operations and sustainability both strive for better working conditions. The workplace improvements in lean improvement are underpinned by a shift toward an engaged, empowered, and well-trained workforce. As a result of visible management, worker training, and standardized labor, lean operations tend to provide improved levels of safety. (Taubitz, 2010). In addition, incentive payments and a typically higher level of compensation have been reported in lean than non-lean factories. (Womack et al., 1990); (MacDuffie and Helper, 1997). These elements, which are all expressly lean, help to clearly develop a long-term working environment. These challenges of sustainability are underpinned by organizational openness of information both inside and across company borders. In every lean organization, the change toward openness is also critical. (Lamming and Hampson, 1996) A lean organization has standardized work patterns and clear communication routes among workers, suppliers, and consumers. (Womack et al., 1990). This openness aids internal governance processes while also minimizing wastage at the firm's perimeter, as just the resources required are brought in, avoiding the bullwhip effect. (Corbett et al., 2006), (Kainuma and Tawara, 2006). Furthermore, community contributions were tied to the organization's beneficial influence in the community in which they operated, such as charity donations and favorably supporting the community (Lee and Shin, 2010). Governance and Ethical dealt with concerns such as socially responsible investing, public disclosure of operations, establishing a clear and documented ethics policy, and guaranteeing legal compliance. (see: (Maignan and Ferrell, 2000); (Turker, 2009). Maintaining a positive reputation in the local community is an explicit aspect of the lean organization's strategy-setting process. While sometimes underestimated, this issue has proved critical to a variety of lean firms. (Womack et al., 2003). For example, since the 1950s, Toyota has placed a strong emphasis on community concerns, particularly those affecting present and past Toyota locations and employees. These aren't merely declarations of philosophy; they're also linked to specific performance indicators.

According to the literature, there are three types of lean social sustainability. (see Figure 7)

1. Workplace lean social sustainability (treat employees fairly)
2. Information transparency with a lean social sustainability
3. Community contributions with a lean social sustainability

Tables 20 Principles of Lean Social Sustainability

Lean Social Sustainability Principles	Authors	Contribution
1. Work force & Safety (Treat employee's right)	(Savitz & Weber, 2006)	Labor practices, Community effects, Human rights, and Product responsibility are all part of the balanced scorecard that reflects social outcome performance in statistics.
	(Piercy and Rich, 2015)	Workforce issues concern how a company handles its employees. 1. Issues with workplace operations 2. Compensation 3.Union relations
	(Storey, 1994).	Lean operations and a sustainable engaged, empowered, and well-trained staff share the goal of improved working conditions.
	(Womack et al., 1990; MacDuffie, 1995)	Incentive payments and a typically higher level of compensation for specifically lean workers also contribute to a more sustainable working environment.
	(Taubitz, 2010).	Through visible management, worker training, and standardized labor, lean operations tend to provide superior levels of safety.
2. Organization Transparency of Information	(Lamming, 1993).	These sustainability challenges are rooted both inside and across company boundaries. In every lean organization, the change toward openness is also critical.
	(Womack et al., 1990)	A lean operation includes standardized work procedures and open lines of communication with employees, vendors, and consumers.
	(Corbert and Klassen, 2006; Kainuma and Taware, 2006).	Supports internal governance processes while also decreasing wastage at the company border by only bringing in the resources that are required, avoiding the bullwhip effect.
	Lee and Shin, 2010	Community contributions were made in response to the organization's beneficial influence in the community in which it operated, such as charity donations and favorable community support.
	Maignan and Ferrell, 2000; Kok et al., 2001; Turker, 2009	Governance and Ethical dealt with concerns such as socially responsible investing, public disclosure of operations, establishing a clear and documented ethics policy, and guaranteeing legal compliance.
3. Community Contribution	Womack and Jones, 2005	Maintaining a positive reputation in the local community is an explicit aspect of the lean organization's strategy-setting process. While sometimes underestimated, this issue has proved critical to a variety of lean firms.



Figures 7 Lean Social Sustainability Frame work

2.15.2 Lean Social Sustainability practices

In this study, the Panizzolo model was applied with minor changes in practices based on a communize comparison of three investigations (Panizzolo, 1998). A study model that envisioned lean manufacturing and included a variety of best lean manufacturing practices in various sections of the organization, all of which were linked to social sustainability in the manufacturing business. Second, compare and contrast with (Piercy and Rich, 2015) Study the adoption of lean operational methods and, separately, the adoption of business practices that have a positive social impact. Finally, in analyzing literature on lean and social sustainability principles, to corroborate the selection of lean manufacturing processes based on the most popular practices. 1. Work force (treat employee right) 2. Information transparency 3. Community contributions (see Figure 8, Table 21)

1. Panizzolo Model 1998

- The finest lean techniques in the categories of Process & Equipment, Manufacturing Planning & Control, Human Resource, and Customer Relationship characterize distinct parts of the firm connected to social sustainability effect.

2. Piercy and Rich Model 2015

- Adopting lean approaches that have a social effect.

3. The research study

- In examining literature under lean and social sustainability in three principles, to ensure the selection of lean manufacturing based on the most frequent practices.

Figures 8 Research idea study of lean social sustainability practices

Table 21 shows the decision to choose the best lean manufacturing practices that have the greatest impact on social benefits, now referred to as "Lean Social Sustainability," as mentioned in all studies and classified by business area to obtain the most precise findings from manufacturing companies that have adopted these methods in the areas listed (Panizzolo, 1998). Considering the regions will allow manufacturing companies to focus their efforts on areas where they may improve their sustainability performance in exchange for particular sustainability measures (Nordin et al., 2010).

Tables 21 Lean social sustainability practices

			Principle (Definition) → 1) Treating employee right 2) Community and region in which a corporation conducts			Lean	Lean&Green	Lean&Social	Lean & Social		Lean & Susainability		
	Area	Practices : Direct positive LM to Social Sustainability	1) Work force (Treat employee right)	2) Information Transparency	3) Community Contribution	Panizzolo (1998)	Gene Fliedner, (2008)	Womack and Jones (2005)	*Other	Glover et al., 2011	Piercy, Niall Rich, Nick (2015)	Lean benefit	sustainability benefit
1	Process & Equipment	1. Kaizen	*			*	*			*	*	engage workers, find solutions to problems	engage workers, improved workplace
2	Manufacturing planning & control	1. Standardized work	*			*	*				*	Increase cross-skill of workers to work across plant; Find best ways of operating.	Safety.
		2. Visual Management - Jidoka - Poka Yoke	*			*					*	Improve quality/layout/safety	Improve safety, improved ease of work life
3	Human Resource	<u>3.1 Workplace operational issues</u> 1. Training	*			*					*	Understand costs of poor quality and how to fix	Engagement, treatment
		2. Group Problem Solving (5 why technique)	*			*	*				*	Increase cross-skill of workers to work across plant; Find best ways of operating.	Safety.
		3. Cross functional Team	*			*					*	reduce reliance on inspection to enforce quality	worker engagement, improved workplace
		4. Employee Involvement and commitment	*			*					*	reduce reliance on inspection to enforce quality	worker engagement, improved workplace
		<u>3.2 Compensation</u> 1. Fair wages and payment, Diversity issue (non discrimination in hiring)	*				*				*	Employees understand cost/benefits to help improve	Better business ethics/engagement.
4	Organization Policy	<u>Community</u> 1. Community Engagement and School/ neighbor engagement			*			*			*	Gain reputation as employer of choice to get best workers	Positive member of community
		2. Charitable giving			*			*			*	Incentivise staff for improvement	Positive member of community
		<u>Transparency</u> 3. Transparency to employee		*					*		*	Employees understand cost/benefits to help improve	Better business ethics/engagement.
		4. Transparency to community		*					*		*	Community understands and supports business	Better business ethics/engagement.
		5. Sustainability audit and public disclosure		*					*		*	Part of transparency/audit culture	Ethical/stakeholder engagement.
5	Customer relationship	1. Customer involvement in quality programs		*		*					*	Trusted company can sell more	Ethically should be honest with customers
		2. Customer involvement in product design		*		*					*	Trusted company can sell more	Ethically should be honest with customers
6	Supplier relationship	1. Transparency to suppliers in open book costing		*					*		*	Gain supplier commitment to long term relationship. No unexpected price rises/problems of low price bids.	Better business ethics/engagement.

* Other : Kok 2001, Turker 2009, Lamming 1993, Corbert and Klassen 2006, Kaiuma and Taware 2006, Tubitz 2010, Womack 1990,

1. Principle of the Workforce

Lean social sustainability practices use the same concept to select practices as lean environment and economic sustainability practices by using a research model that conceptualized lean manufacturing with a number of its best lean manufacturing practices characterizing different areas of the company developed by a research model that conceptualized lean manufacturing (Panizzolo, 1998). In this study, the Panizzolo model was applied with minor changes in practices based on a communize comparison of three investigations (Panizzolo, 1998). A study model that theorized lean manufacturing and characterized several sectors of the organization with a number of its finest lean manufacturing practices. To discover the same mention from the research of Panizzolo's framework (Fliedner, 2008) The seven lean principles are routinely pursued by businesses via the use of various Lean techniques and tools, and it has been discovered that there is a link between the areas of process and equipment and manufacturing planning and control in terms of labor force. Finally, implement what you've learned. (Piercy and Rich, 2015) There are a few regularly utilized strategies and techniques that provide both lean and sustainable advantages. Four lean social sustainability principles have a total of fourteen beneficial effects on the workforce. Total four practices are 1) Kaizen, 2) standardization 3) visual management and 4) human resource issues

1) Kaizen

Employee attitudes and commitment in the workplace benefit from lean to engage employees, discover solutions to challenges, and benefit from sustainability to engage workers and enhance the workplace. According to them, (Glover et al., 2011) contribution that has been investigated The impact of kaizen on work area employee attitudes and commitment was investigated using a multi-site field study methodology applied to the criteria of eight manufacturing companies, and it was discovered that there was a positive relationship between Kaizen event, work area, and post-event characteristics vs. work area attitude and commitment. Kaizen method engages workers in group problem thinking to solve problems and reduces dependency on inspection to enforce quality and safety concerns (Piercy and Rich, 2015, Panizzolo, 1998, Fliedner, 2008)

2) Standardized work

The practice of LM has an influence on increasing worker cross-skilling to work across plants; finding the best ways to operate and maintain a safe environment is a benefit to long-term sustainability (Piercy and Rich, 2015, Panizzolo, 1998, Fliedner, 2008).

When working with firms that don't have a lean orientation, they usually start by talking to process operators about what they do. Standard work is particularly interested in the steps that process operators must take to ensure that the process is successful.(Allwood & Pentland, 2016). According to (Dennis, 2007; George , 2003), In terms of methods utilized, personnel movement, and output rate, work should be carried out in accordance with an established standard (takt time, cycle time, work sequence and in-process stock). The following are the most important parts of standardization work to comprehend: (Bicheno & Holweg, 2008)

- Whenever a better technique is identified, standard work should be updated.
- Standard work increases consistency and reduces variance by having the job done the same way every time.
- Standard work is necessary for ongoing improvement as you progress from one standard to the next.

The advantage of standardized work for organization is that it is easy to follow.(Dennis, 2007)

- Process stability is achieved by the use of distinct stop and start points for each process.
- Kaizen
- Better training
- Improved auditing and problem-solving
- Employee involvement
- Poka-yoke (error of mistake proofing)
- Organizational learning

As a result, standardized work forms serve as a foundation for kaizen, or continuous improvement. The new standard becomes the foundation for future improvements as the old standard is improved, and improving standardized work is a never-ending process.

3) Management of Visuals

The visual management system, which includes Jidoka (autonomy) and Poka-yoke (error-proofing) equipment. Visual management is an immensely critical tool in the realm of Lean and may be thought of as the interface between data and people. Visual management use spontaneous visual signals to make short, correct information available to people who need it at all times in the workplace (Shingo, 1986).

1) Jidoka- Autonomation

The term jidoka utilized in the TPS (Toyota Production System) may be described as "automation with a human touch," according to Toyota Global.com. The name jidoka comes from Sakichi Toyoda, the Toyota Group's founder, who invented the automated loom. An automated loom is a machine that automatically spins thread for cloth and weaves textiles. Jidoka is a method for preventing defective material from progressing through the manufacturing chain and identifying and correcting system flaws. This leads to process enhancements that increase quality by removing the fundamental causes of problems. Jidoka is useful for visual control. Because equipment comes to a halt when a problem occurs, a single operator can visually monitor and operate a large number of machines. Toyota plants employ a problem display board system called "andon" as a crucial tool for this "visual control" or "problem visualization," which allows operators to spot problems in the production line with just a glance. (Monden, 2011). The term andon alludes to a Japanese paper-covered lamp stand, although it simply refers to a light in Toyota. (Association, 1986) To conclude, Jidoko is an autonomization methodology for defect control in manufacturing. The following are some of the most important Jidoka methods to review: Kaizen, 5 whys and poka-yoke.

2) Poka-yoke / Error proof equipment

Poka-yoke (Poka-yoke) is a Japanese Error proofing is a technique for achieving 100% quality assurance. For example, most automobiles include thousands of poka yokes for mistake proofing. There could be several such devices while filling your gas tank, such as a device to connect your gas cap to the car so you don't lose it;

an automatic shut off on the gas pump; a ratcheting device to prevent overtightening of the gas cap; and a warning light on the door to warn you if it is not properly closed (Wilson, 2010). Shingo is credited with turning the concept into a powerful instrument for attaining zero errors and, eventually, eliminating quality control inspection. To avoid (yokeru) unintended errors (poka), he coined the word poka-yoke, which means "mistake-proofing" or "fail-sating." It is based on the principle of respecting employees' intellect. It frees a worker's time and attention to pursue more creative and value-adding activities by taking over repetitive chores or actions that rely on attentiveness or recollection.(Shingo, 1986). Source inspection, which refers to a fault as a consequence, or an effect, frequently generated by a minor error, is one of the most successful inspection approaches. The error can be rectified before it becomes a defect by doing a complete check at the source. Zero Quality Control (ZQC) or "Defects=Zero" can be accomplished (Shimbun, 1989). According to (Shingo, 1986), when used properly, a system may lead to "Defects=Zero." Poka-yoke devices, in particular, play a key role in ZQC as instruments for 100 percent inspection. This is a low-cost strategy for eliminating or at the very least decreasing faults and errors that result in a dangerous working environment. Treating your employees fairly is the goal of social sustainability. This is also known as human capital, and it refers to a company's fair and helpful business practices toward its employees as well as the community and region in which it operates. Workforce Issues, according to (Piercy and Rich, 2015) , are connected to how a firm handles its employees. Lean operations and sustainability both strive for better working conditions. The workplace improvements in lean improvement are underpinned by a shift toward an engaged, empowered, and well-trained workforce. (Storey, 1994). As a result of visible management, worker training, and standardized labor, lean operations tend to provide improved levels of safety. (Taubitz, 2010). In addition, incentive payments and a typically higher level of compensation have been reported in lean than non-lean factories. (Womack et al., 1990) (MacDuffie and Helper, 1997). These elements, which are all expressly lean, help to clearly develop a long-term working environment.

4) Human Resources

Human resource concerns with the labor force in manufacturing are divided into four categories: 1) group problem solving, 2) cross functional team, 3) employee commitment and participation, and 4) compensation to employee.

1) Group problem solving

The benefit of group problem solving in lean is that it reduces the need on inspection to enforce quality and, in the long run, it engages workers and improves the workplace (Panizzolo, 1998, Piercy and Rich, 2015) To ensure quality, less dependence on inspection is required. The 5 whys approach is one of the techniques used in LM for group issue solving. The Toyota Motor Corporation created and fine-tuned the 5 Whys methodology as a vital component of their problem-solving training. According to (Ohno, 1988) "By repeating why five times, the essence of the problem as well as its answer becomes clear," according to Toyota's scientific method. In the Toyota culture, the team is encouraged to investigate each problem until the fundamental cause is discovered. We must "ask 'why' five times about every topic" and "observe the factory floor without prejudices." In the Analyze phase, a methodology known as the 5 Whys is employed. This simple yet powerful technique to problem resolution encourages deep thought via inquiry and can be readily changed and used to a wide range of issues (Serrat, 2017). According to (Ohno, 1988)

There are three crucial components to using the Five Whys methodology effectively:

(i) Effective usage of the Five Whys methodology requires three critical components:
(ii) Complete truthfulness in answering queries,
(iii) The desire to solve issues by getting to the root of them.

As a result, it is one of the most effective and straightforward techniques to complete without statistical analysis to assist in identifying the underlying cause of a problem, removing all types of wastes, and ultimately assisting the organization in achieving flow, pull, and perfection.

2) Cross functional team

The benefit of a cross-functional team in lean is that it reduces the need on inspection to enforce quality and, in the long run, it engages workers and improves the workplace.(Panizzolo, 1998, Piercy and Rich, 2015). The empirical findings support the necessity of human resources in implementing lean manufacturing concepts. In particular, managers believe that workers' participation in continuous quality improvement initiatives, the growth of tier autonomy and responsibility, and the presence of multi-functional staff have all been critical for improving business performance.

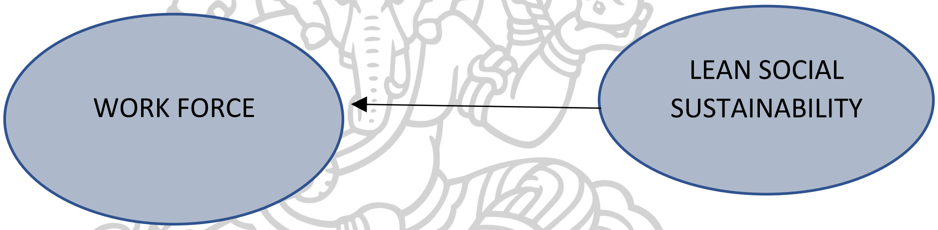
3) Employee commitment and participation

Employee participation provides an advantage in lean by reducing the need on inspection to enforce quality, as well as engaging workers and improving the workplace's sustainability (Panizzolo, 1998, Piercy and Rich, 2015). Workers' participation and empowerment help to create value (Worley, 2004). For the concept of continuous improvement to be realized, shop-floor personnel must be actively involved in improvement efforts and participate in improvement activities. (Jørgensen et al., 2004). A decentralized control system encourages personal engagement and moves decision-making below in the organization, where the data is available. Furthermore, because employees are familiar with the product and process, their engagement is crucial for the implementation of pollution avoidance initiatives (Kaplan and Wisner, 2009). The organizations analyzed have used innovative approaches in all of the core processes that make up human resource management in order to encourage employee contributions and boost employee empowerment and accountability (i.e. recruitment and selection, education and training and evaluation and reward). In terms of evaluation and reward, for example, methods have been implemented with the goal of rewarding and encouraging conduct based on personal initiative and connections rather than hierarchy(Rothenberg et al., 2001). Workplace systems and human resource strategies can help reduce waste and pollution production (Florida, 1996, King and Lenox, 2001). Workforce commitment provides an advantage in lean by reducing the need on inspection to enforce quality, as well as engaging workers and improving the workplace's sustainability. (Panizzolo, 1998, Piercy and Rich, 2015) A favorable association between worker engagement/involvement and environmental performance has already been discovered in research. (Florida, 1996) (Kitazawa et al., 2000, Sarkis, 2003).

4) Compensation - Establishment to employees

Fair salaries and payment, as well as concerns of diversity, were all part of the compensation package (non-discrimination in hiring) (Piercy and Rich, 2015, Womack et al., 1990, MacDuffie and Helper, 1997).

Four lean social sustainability principles have a total of fourteen beneficial effects on the workforce. The following are the four practices: 1) Kaizen, 2) standardization 3) visual management and 4) human resource issues (See Figure 9 and Table 22)



Figures 9 Lean Social Sustainability on work force principle

Tables 22 Work Force dimension practices and benefits

No.	Dimension	Practices	Benefit of support work force
1.	Work Force	Kaizen	Employee attitudes should be improved.
2.	Work Force	Kaizen	Look for a safe solution.
3.	Work Force	Standardized Work	Reduce production variances.
4.	Work Force	Standardize work	Find the best way to keep environment safe.
5.	Work Force	Standardize work	Takt time helps to increase safety.
6.	Work Force	Visual management	Jidoka is a tool for visualizing problems.
7.	Work Force	Visual management	Poka-yoke is a tool for visualizing problems.

8.	Work Force	Visual Management	Enhance security
9.	Work Force	Human Resource	5 reasons why involving employees in the workplace improves productivity
10.	Work Force	Human Resource	5 reasons to improve cross-skilling
11.	Work Force	Human Resource	Employees are engaged by a cross-Functional team
12.	Work Force	Human Resource	Workers on the shop floor are constantly improving
13.	Work Force	Human Resource	As a result of the improvements, the shop floor was evaluated
14.	Work Force	Human Resource	Employees' compensation is established

2. Transparency of information

According to the direct beneficial link between lean manufacturing processes and social sustainability, organizations become more open of information. (Wilson, 2010), The notion of transparency is that the performance of a procedure or an entire line may be "seen" just by being present on the floor." When transparency is effectively established, a manager may tell in one or two minutes whether his process is working as intended, and if it isn't, the manager may rapidly identify the issue areas.

These concerns of sustainability are based on information transparency both inside and between firms. In every lean organization, the change toward openness is also critical (Lamming and Hampson, 1996). A lean organization has standardized work patterns and clear communication routes among workers, suppliers, and consumers (Womack et al., 1990). This openness aids internal governance processes while also minimizing wastage at the firm's perimeter, as just the resources required are brought in, avoiding the bullwhip effect. (Corbett (Corbett et al., 2006) (Kainuma and Tawara, 2006).

As a result, the goal of having transparency is to be able to discern and determine when something has changed, as well as to have the essential information readily available in order to execute quick reaction. Internal governance procedures, as well as openness in the sustainability problem, are supported by PDCA and are essential in any lean firm.

Five actions that promote information transparency have a good influence on lean social sustainability: 1) charitable giving, 2) transparency to employee, 3) sustainability audit and public disclosure, 4) customer involvement in quality programs and product design, and 5) Open book costing provides suppliers with transparency.

1) Charitable giving

Community is one of the sustainability goals. This was a reference to the organization's beneficial influence in the community in which they operated, such as by charity donations and favorably supporting the community. (Lee and Shin, 2010). Maintaining a positive reputation in the local community is an explicit aspect of the lean organization's strategy-setting process. While sometimes underestimated, this issue has proved critical to a variety of lean firms (Womack and Jones, 2005). For example, since the 1950s, Toyota has placed a strong emphasis on community concerns, particularly those affecting present and past Toyota locations and employees. These aren't merely declarations of philosophy; they're also linked to specific performance indicators. Community contributions are those that relate to the organization's beneficial influence in the community in which it functioned, such as charity donations and positively supporting the community. (Lee and Shin, 2010) .

2) Employee transparency

The organization is open with its employees and provides perks in terms of cost/benefit analysis to aid in improvement. Better corporate ethics/engagement has a long-term advantage for sustainability (Piercy and Rich, 2015, Lamming and Hampson, 1996, Corbett et al., 2006, Kainuma and Tawara, 2006).

3) Auditing for sustainability and public transparency

In terms of part of a transparency/audit culture, the organization has a sustainability audit, and public disclosure provides an advantage in lean. Better corporate ethics/engagement has a long-term advantage for sustainability. (Piercy and Rich, 2015) . Governance and Ethical dealt with concerns such as socially responsible investing, public disclosure of operations, establishing a clear and documented ethics policy, and guaranteeing legal compliance (Maignan and Ferrell, 2000, Turker, 2009).

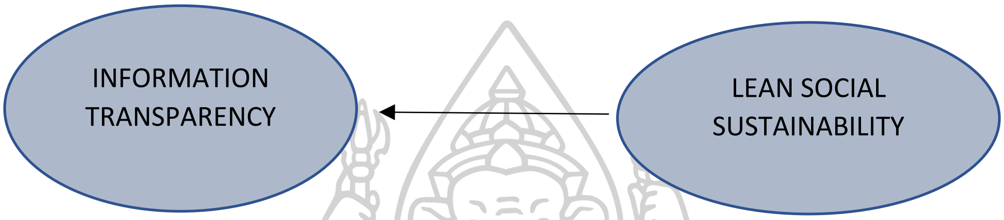
4) Participation of customers

Adopting a lean manufacturing strategy also entails building creative client interactions. (Panizzolo, 1998, Shah and Ward, 2003). Because customers evaluate quality and value, it will be vital for businesses to cultivate positive relationships with them. In order to maintain a positive client connection, businesses must prioritize the needs of their customers. What's more, their requests are completely questionable. As a result, you'll be able to react to market changes more quickly. This is critical due to the need of obtaining a good match between client requirements and production flow (Wong et al., 2009) (McDougall and Levesque, 2000). Customer relationship described as a bundle of polishes with the main objective for being there being to improve consumer happiness, manage customer objections, and build long-term relationships with customers. Close client relationships aid an organization's ability to maintain customer loyalty, distinguish its product from rivals, and aggressively seek to offer additional value to its consumers. Customer participation in quality programs and product design provides an advantage in lean because a trustworthy firm can sell more and sustainably since it is ethical to be honest with consumers. (Panizzolo, 1998, Shah and Ward, 2003).

5) Suppliers' transparency

In open book costing, the firm is transparent to suppliers, which benefits lean in terms of gaining supplier commitment to long-term relationships. There are no sudden price increases or difficulties with low-price bids. Better corporate ethics/engagement has a long-term advantage for sustainability. (Piercy and Rich, 2015, Lamming and Hampson, 1996, Corbett et al., 2006, Kainuma and Tawara, 2006).

Five information transparency activities, including charitable giving, transparency to employees, sustainability audit and public disclosure, customer involvement in quality programs and product design, and transparency to suppliers in open book costing, all have a positive impact on lean social sustainability. (See Figure 10 and Table 23)



Figures 10 Lean Social Sustainability on information transparency principle

Tables 23 Information transparency dimension practices and benefits

No.	Dimension	Practices	Benefit of information transparency
1.	Information Transparency	Charitable Giving	A positive reputation
2.	Information Transparency	Employee	Help improvement
3.	Information Transparency	Audit and public disclosure	Transparency/audit culture
4.	Information Transparency	Customer in quality program	Sustain customer loyalty
5.	Information Transparency	Suppliers in costing	better business ethics

3. Community contributions

The involvement of the community is an element of the organization's openness of information. In community-based lean social sustainability strategies, the study of (Piercy and Rich, 2015, Womack et al., 2003). The contribution of the community has a role in the organization's information openness. The study of lean social sustainability techniques in the community.

There are four types of community contributions that have a good influence on lean social sustainability: 1) community engagement, 2) employee involvement in the community and civic affair, 3) charitable donations, and 4) clear performance metrics in community.

1) Community Engagement

Community Engagement has a lean benefit of gaining a reputation as an employer of choice, a sustainability benefit of attracting the best employees, a positive member of the community, and being a good corporate citizen, and a sustainability benefit of being a positive member of the community, and a sustainability benefit of being a good corporate citizen. Corporate social responsibility, sustainable business practices, corporate governance, ethical behavior, and integrity and compliance management have all seen considerable increases in interest over the last ten years. (Waddock and Governance in Global Business, 2005). Not only do stakeholders expect businesses to pay more attention to norms, values, and principles; businesses themselves are recognizing the significance of ethical business practices. (Waddock and Governance in Global Business, 2005). Stakeholders illustrate the concerns that are handled in the evaluated codes. Consumers, investors, employees, society, and the natural environment are all addressed in most corporate rules, whether in detail or in brevity. Multinational businesses' business codes governing their duties to stakeholders in the field of society (or local community), including (Kaptein, 2004).

2) Participation of employees in community and civic affairs

Take part in with community organizations such as government agencies and business groups devoted to improving health, education, product safety, workplace safety, and prosperity is one of the activities. (Kaptein, 2004).

3) Charitable donations

Supporting/participating in local activities that promote peace, security, diversity, and social integration as a good corporate citizen through charity donations, educational and cultural contributions. There are several that are tied to the organization's good influence on the community in which they operate. (Lee and Shin, 2010).

4) Clear performance metrics in community contributions

Community contributions are more than simply declarations of principle; they are also linked to specific performance measures. Maintaining a positive reputation in the local community is an explicit aspect of the lean organization's strategy-setting process. While sometimes underestimated, this issue has proved critical to a variety of lean firms (Womack et al., 2003). For example, since the 1950s, Toyota has placed a strong emphasis on community concerns, particularly those affecting present and past Toyota locations and employees.

Community involvement, employee participation in community and civic affairs, charity donations, and clear performance indicators in the community are four community contribution activities that have a beneficial influence on lean social sustainability (See Figure 11 and table 24).

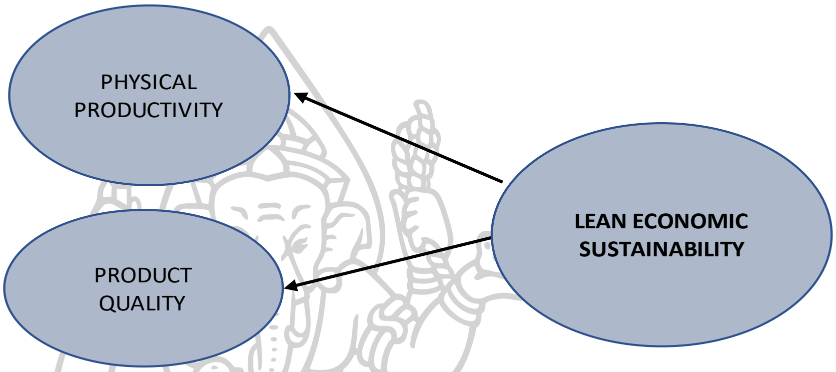
Figures 11 Lean Social Sustainability on community contribution principle

Tables 24 Community Contribution dimension practices and benefits

No.	Dimension	Practices	Benefit of community contribution
1.	Community Contribution	Engagement activity	Employer of choice
2.	Community Contribution	Employee participate	Get best positive member
3.	Community Contribution	Charity donations	Gain reputation
4.	Community Contribution	Performance metrics	Explicit part of the set strategy

2.16 Economic Sustainability and Lean Manufacturing

As a fundamental premise of lean manufacturing, (Oliver et al., 1996) a district collection of practices that may be found both within the production and in the supply chain Just-in-time manufacturing, small batch sizes, and low inventories are all used by lean manufacturers inside the facility. On the shop floor, operators are organized into small groups, and these small groups take on many of the duties that have historically been the domain of mass-professional production's support services. This methodology is designed to promote learning and development throughout the process. Quality circles and employee suggestion programs are examples of small problem-solving groups (see Figure 12).



Figures 12 Lean Economic Sustainability Frame Work

2.16.1 Lean manufacturing and economic results have a direct beneficial link

Tables 25 Critical Factors for achieving economic sustainability that come from Lean Management.

Articles	Area of applicant	Key contribution	CSF to the result
Lewis (2000)	Automotive	Obtaining and maintaining strategic resources is critical. (Resource-Based View) developed as part of the LM learning curve. The success of LM and its long-term viability are dependent on the firm (market, technology or supply chain structure).	Hold on to the strategic assets.
Maskell and Baggaley (2003)	Theoretical	Creating a roadmap for transforming a standard accounting system into one that supports and facilitates LM	Accounting should be lean.

Hines et al. (2008)	Theoretical	l Identifying critical criteria for long-term LM success. It's critical to address both the less visible (strategic planning and implementation, management leadership, employee behavior and commitment) and the more visible (process management, LM technologies, and tools) aspects of the business.	Less visible are strategy and its implementation, management leadership, employee behavior and commitment, and process management, as well as LM technology and tools.
Turesky and Connell (2010)	Automotive	Identifying facilitator and inhibitor variables at various stages of the LM transition. Important aspects to consider throughout the LM findings' long-term viability stage.	
Lewis (2000)	Automotive	It is vital to obtain and preserve strategic resources. As part of the LM learning curve, (Resource-Based View) was developed. The firm's profitability and long-term viability are contingent on LM's performance (market, technology or supply chain structure).	Keep the important assets safe.
Lucey et al. (2005)	Multisectoral	Identifying important criteria for long-term LM success. People and change management challenges are stressed.	People and change management challenges are stressed.

Economic sustainability is typically well understood, therefore there is a good fit between lean management and economic sustainability. It is operationalized as production or manufacturing costs at the plant level. The triple-bottom-line notion indicates that businesses should not only engage in socially and environmentally responsible conduct, but also reap financial benefits as a result of doing so (Gimenez et al., 2012).

Tables 26 Model and Framework to assessing contribute to economic sustainability

Author/s	Area of applicant	Key contribution	Type of contribution
Bateman and David (2002)	Automotive	The creation of a model for evaluating the long-term viability of LMs. Inside and across manufacturing shop-floor cells, the focus is on facilitators and inhibitors. There are several intermediary phases in the long-term viability of LM findings.	Model of Assessing LM sustainability
Lucey et al. (2004)	Pharmaceutical	Creating a long-term LM sustainability framework (key factors include communication and people's commitment).	A foundation for long-term LM sustainability.
Jørgensen et al. (2007)	Multisectoral	The creation of a capacity framework using two approaches: technical and organizational. This timeline depicts the company's progress toward LM.	The company's status framework's capability
Bhasin (2008)	Theoretical	To sustain the LM outcomes, a dynamic multi-dimensional performance framework was developed with 38 indicators and five major dimensions: financial, customer/market, process, people, and future.	Performance on several levels Keep the outcomes structure in place.

Author/s	Area of applicant	Key contribution	Type of contribution
Fullerton and Wempe (2009)	Multisectoral	The influence of LM on operational and financial results The use of non-financial measures has an impact on the LM financial performance link (operational). It is critical to use appropriate non-financial	Non-financial measures are needed to keep the LM benefits framework going.

		measurement frameworks in order to retain LM benefits.	
Ho (2010)	Multisectoral	The creation of a thorough plan for achieving long-term objectives. This includes topics such as ISO 9000, ISO 14001, OHSAS 18001, and Six Sigma. Model for evaluation.	Model achieving sustainable Results
Sawhney et al. (2010)	Theoretical	In order to maintain Lean outcomes, an integrated dependability model must be developed. Failure Mode and Effects Analysis (FMEA)-based model (FMEA). Personnel, equipment, supplies, and schedules are all critical to the long-term success of LM.	Maintain lean outcomes using this model.

2.16.2 Principles of Economic Sustainability in a Lean Economy

Positive financial benefits may be generated in the manufacturing process, according to the data (Gimenez et al., 2012) It is operationalized as production or manufacturing costs at the plant level, and it is the alignment of lean management with economic sustainability. The reduction of manufacturing expenses connected to units per work hour, product quality from the manufacturing process, and overproduction, which results in an excess of finished products inventories.

1. Units per labor hour are a measure of physical productivity

Physical productivity in units per labor hour is a measure of plant performance, is one of the outcomes of process optimization that generates positive financial advantages. The yearly units of production of each facility were divided by the yearly labor input to arrive at this figure. Consolidation, the length of the working day, overtime, absence, and the complexity of the product all necessitated changes. Customers nowadays want high-quality goods with a wide range of manufacturing needs, as well as small-lot deliveries with short lead times. Manufacturers have responded by implementing efforts such as setup time reduction, cellular production, and quality enhancement in response to these needs. Smaller batch sizes necessitate more frequent setups. As a result, minimizing setup time (and cost) is becoming increasingly important in order to service clients in a timely and profitable manner (Piercy and Rich, 2015). Furthermore, businesses that rely solely on mass manufacturing are frequently ill-equipped to compete in today's market. As a result, many businesses have turned to cellular manufacturing for its flexibility and efficiency. Finally, customers' increased concern about quality has prompted manufacturers to engage in quality efforts in order to keep and extend their client bases while also lowering the expenses associated with quality failures. Both expenses and benefits are associated with lean approaches. As a result, the impact on net financial performance is a research subject. Prior research has yielded a mixed bag of results. According to several research, using JIT or TQM does not increase profitability. (Huson and Nanda, 1995; Ittner and Larcker, 1995; Mohrman et al., 1995; Balakrishnan et al., 1996; Lau, 2002; Ahmad et al., 2004). Other study, on the other hand, supports a link between contemporary production processes and financial performance. (Chenhall, 1997; Easton and Jarrell, 1998; Callen et al., 2000, 2003; Kinney and Wempe, 2002; Eriksson and Hansson, 2003; Fullerton et al., 2003; Kaynak, 2003; Nahm et al., 2003).

Furthermore, owing to a lack of response to demand changes, overproduction and excess inventory of completed items have a detrimental influence on a company's profitability. When demand exceeds capacity, the problem may go unnoticed since producing at full capacity is the best approach to handle excessive demand. However, when demand declines, overproduction and excess finished product inventory become a severe problem.(Bergenwall et al., 2012). Manufacturing of cells assisting the company in improving job shop production The components to be manufactured must be categorized into families based on their resemblance, and line balancing must be performed to complete procedures in a given area and acquire supplies at a pace specified by an average of customer demand. (Takt time) (Fullerton et al., 2003).

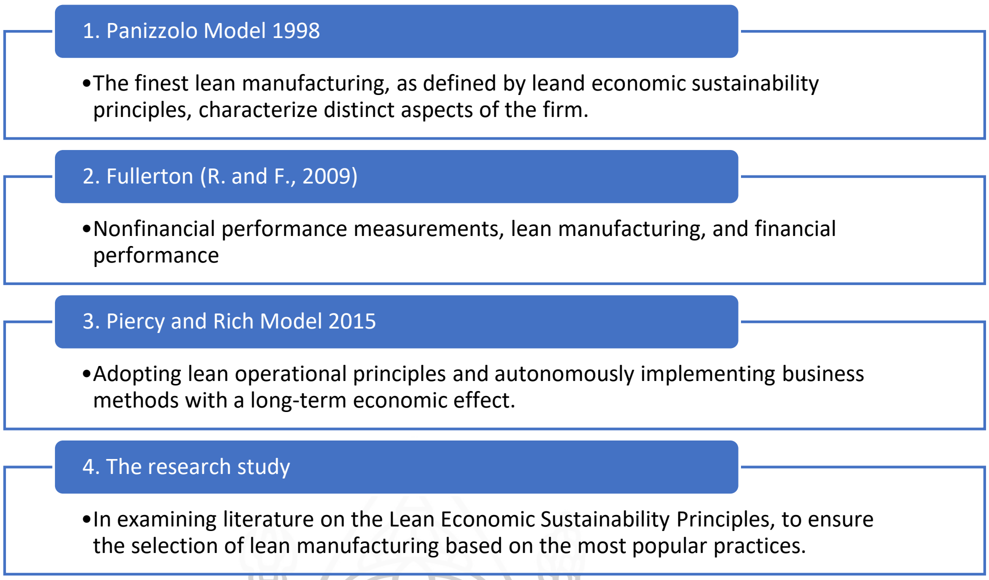
2. Principle of product quality from the process – Defect unit

The quality of the product produced throughout the production process was also used to assess performance. Defective units in parts per million, as reported to the factories by their customers during the same twelve-month period, were used to determine quality. Once obvious manufacturing process issues are resolved, the failure rate may be lowered, resulting in increased productivity.(Lieberman and Demeester, 1999, F. et al., 2006). The factory's problem-solving ability will determine how, if, and when this occurs (Sakakibara et al., 1997). These JIT infrastructures should be mentioned. When an issue arises, employees or groups of employees must determine the problem's fundamental cause and then create, test, and implement a remedy. Some types of production waste result from issues that need the utilization of WIP inventories. Productivity increases once this waste is eradicated, whether it be waste of resources, labor time, or machine time. Furthermore, the end product's quality may increase, allowing the company to charge higher prices or reduce warranty expenses.

2.16.3 Economic sustainability approaches that are lean

Lean economic sustainability practices use the same concept to select practices as lean environmental sustainability practices by utilizing a research model that conceptualized lean manufacturing with a number of its best lean manufacturing practices characterizing different areas of the company developed by a research model (Panizzolo, 1998).

The figure 13 have demonstrated this study to determine which best lean manufacturing practices impact economic benefits that are now referred to as "Lean economic sustainability," based on the principles mentioned in all three Panizzolo, Fullerton, and Piercy and Rich studies, and then classify by business area to obtain the most specific results from manufacturing that have implemented these practices. Considering the regions will allow manufacturing companies to focus their efforts on areas where they may improve their economic sustainability performance in exchange for particular sustainability activities (Nordin et al., 2010).



Figures 13 Study of lean economic sustainability strategies as a research topic

1. Panizzolo Model 1998

In this study, the Panizzolo model was used to modify practices that were chosen only for their relevance to lean economic sustainability principles in the domains of process and equipment, as well as supplier relationships. It arose from a comparison of the three studies from the communize (Panizzolo, 1998). A study model that theorized lean manufacturing and characterized several sectors of the organization with a number of its finest lean manufacturing practices.

Tables 27 Panizzolo framework of optimal lean manufacturing methods for different sections of the organization in terms of lean economic sustainability principles

No. Area	Code	Lean manufacturing practices
Process & Equipment	PE1	Kaizen
	PE2	5S
	PE3	Setup time reduction
	PE4	Cellular manufacturing

	PE5	Continuous flow
	PE6	Equipment layout
	PE7	Product design – simplicity
	PE8	Error proof equipment
	PE9	Preventive maintenance
Supplier relationships	SR1	JIT delivery
	SR2	Supplier quality level
	SR3	Supplier involve quality improve
	SR4	Supplier involve product design

2. Fullerton (R. and F., 2009)

Second, use the Fullerton research. (R. and F., 2009). Financial performance, nonfinancial performance metrics, and lean manufacturing Setup time reduction, cellular manufacturing, and quality improvement initiatives are some of the Lean manufacturing approaches linked to economic sustainability concepts that have had varying direct benefits on profitability (see Table 28).

Tables 28 Lean manufacturing financial performance

Lean manufacturing practices	Code	Activities
Set up time reduction	SU1.	Redesign's equipment shorten setup time
	SU2.	Uses special tools to shorten setup time
	SU3.	Trains employees to reduce setup time
	SU4.	Redesigns jigs, fixtures short setup time
Cellular manufacturing	CM1.	Similar processing requirements
	CM2.	Similar routing requirements
	CM3.	Similar designs

Quality improvement	QI1.	Conducts process capability studies
	QI2.	Designs experiments (Taguchi method)
	QI3.	Statistical process control (SPC) charts

3. Piercy and Rich Model, 2015

Finally, compare and contrast (Piercy and Rich, 2015) investigate the adoption of lean operational methods as well as the uptake of business practices that have an influence on economic sustainability. According to them, (Piercy and Rich, 2015) The adoption of lean operational strategies, as well as business approaches linked to sustainability and corporate profitability, is on the rise. The lean approach of reducing setup time or rapid changeover benefits the lean business by allowing it to run in smaller batches and reducing material losses during changeover, both of which are beneficial in terms of sustainability. Cellular manufacturing benefits the lean company by improving quality, cost, productivity, and dependability, as well as contributing to lower energy, material, and pollutant waste consumption, all of which enhance sustainability. Quality enhancement benefits the lean business because it can produce better goods at cheaper costs, increasing profitability, and the client receives consistent quality, which is beneficial from a sustainability standpoint.

4. The research project

In examining literature on the Lean Economic Sustainability Principles, the verifies the selection of lean manufacturing methods based on the most popular techniques. In the physical productivity concept, there were five lean economic sustainability practices, and in the product quality principle, there were nine lean economic sustainability practices (See Table 29 And 30).

Tables 29 Lean Economic Sustainability Practices

No.	Dimension	Practices

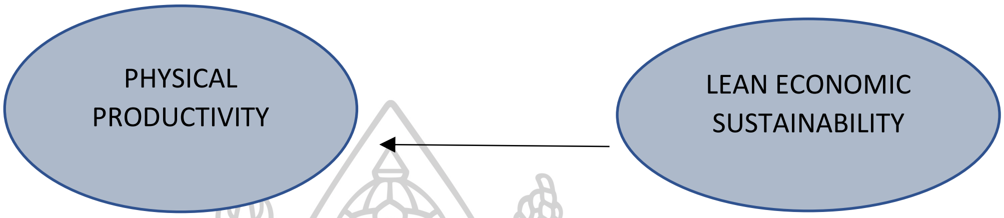
1.	Physical Productivity	SMED reduces product costs by reduce setup time
2.	Physical Productivity	Increased productivity by cellular manufacturing
3.	Physical Productivity	The approach of a current supplier
4.	Physical Productivity	Collaboration with the supplier was documented
5.	Physical Productivity	Keeping track of supplier productivity
6.	Product Quality	Keeping an eye on supplier quality
7.	Product Quality	To accomplish the economic aim, suppliers trained
8.	Product Quality	Provide suppliers with incentives
9.	Product Quality	Quality management processes are being improved
10.	Product Quality	FMEA is a methodology for improving quality
11.	Product Quality	SPC is a methodology for improving quality
12.	Product Quality	DOE's strategy for improving quality
13.	Product Quality	Affinity diagram or cause and effect diagram
14.	Product Quality	Create a culture of excellence

Tables 30 Practices and principles of lean economic sustainability.

Area	Practices : Direct positive LM to Economic Sustainability	Principle (Definition): Improve manufacturing cost — 1) Unit per labour hour (Physical productivity)	2) Product quality from process (Defect unit)	Lean: Panizzolo (1998)	Lean&Economic: Fullerton (2008)	Lean & Susainability: Piercy, Niall Rich, Nick (2015)	Lean benefit	sustainability benefit
Process & Equipment	1. Set up time reduction	*		*	*	*	Run smaller batches	Reduce material losses from changeover (waste)
	2. Cellular manufacturing	*		*	*	*	Quality improvement. Cost improvement. Productivity improvement. Reliability improvement.	Less energy consumption. Less material consumption. Less pollution/waste.
	3. Quality Improvement		*	*	*	*	Make better products at lower cost to increase profitability	Customer gets reliable quality.
Supplier Relationship	1. Supplier Quality Improvement - Existing suppliers - Appropriate monitoring performance - Provide incentive	*	*	*	*	*	Make better products at lower cost to increase profitability	Customer gets reliable quality.

1. Physical Productivity

In the physical productivity principle, there are five lean economic sustainability strategies that result in positive financial results, including : 1) Set up time reduction, 2) Cellular Manufacturing, 3) Existing supplier’s approach, 4) Collaborative documented with supplier, and 5) Tracking supplier productivity performance (see Figure 14 and Table 31).



Figures 14 Lean Economic Sustainability on physical productivity principle

Tables 31 Physical Productivity practices

No.	Dimension	Practices
1.	Physical Productivity	SMED reduces production costs by reducing Set up time
2.	Physical Productivity	Increased productivity through cellular manufacturing
3.	Physical Productivity	The approach of a current supplier
4.	Physical Productivity	Collaboration with the supplier was documented
5.	Physical Productivity	Keeping track of supplier productivity

1) Set up time reduction/ Quick change over

Smaller batch sizes necessitate more frequent setups. As a result, minimizing setup time (and cost) is becoming increasingly important in order to service clients in a timely and profitable manner (R. and F., 2009).

SMED (Single minute exchange of dies) / OTS (One touch set up)

Set up time reduction - SMED lower manufacturing cost

Customers nowadays want high-quality goods with a wide range of manufacturing needs, as well as small-lot deliveries with short lead times. Manufacturers have responded by implementing efforts such as setup time reduction, cellular production, and quality enhancement in response to these needs. Smaller batch sizes necessitate more frequent setups. As a result, minimizing setup time (and cost) is becoming increasingly important in order to service clients in a timely and profitable manner.(Piercy and Rich, 2015). Reduced setup time has mutual benefits for LM in terms of the factory being able to run in smaller batches, as well as sustainability advantages in terms of decreasing material losses during changeover, which means less waste. Other advantages of a successful SMED program include cheaper production costs (faster changeovers imply less downtime), improved customer response (smaller lot sizes allow for more flexible scheduling), and reduced inventory levels (smaller lot sizes result in lower inventory levels) (Shingo, 1996). Therefore, set up time reduction improve in the process that create positive financial gains. It is plant performance to improve physical productivity measure by units per labor hour.

2. Work Cells / Cellular manufacturing

This is the process of organizing processes and/or personnel in a cell (U-shaped, for example) rather of a standard straight assembly line. The cellular approach, among other things, provides for greater use of personnel and improved communication. Kilpatrick (Kilpatrick, 2003). According to them, (Press, 2006) Continuous flow requires a well-designed cell. While the typical U-shaped cell is an LM mainstay, there are a variety of cell configuration and staffing approaches to choose from. As a result, it varies per organization and how they approach cell setup. One lean tool that may assist a firm in redesigning a cell from the ground up is 3P. In terms of (R. and F., 2009, Metternich et al., 2013) demonstrate that the company uses Principles of Cellular Manufacturing to group comparable processing needs, comparable routing needs, comparable designs and parts, design cell creation and layout, line balance, and job shop productivity improvements. The concept of Group Technology was initially proposed by Mitrofanov and Burbridge, and it entails grouping comparable pieces in order to boost efficiency. As a result, Cellular Manufacturing refers to the grouping of various equipment used to produce this family of products. Cells can incorporate a variety of technologies to span the whole manufacturing process. Work is dispersed from one complicated machining center to multiple basic machine tools within machining cells in particular. This equipment should ideally be tailored to the concrete machining operation ("right-sized equipment"). The work item is moved from machine to machine, where it is treated in various clamping sequences. This is normally done manually by an operator in a lean setting. According to them,(Drolet et al., 1996) explain the type of cellular manufacturing in three by following.

Using cellular manufacturing to boost productivity is a great way to go

Quality enhancement, cost savings, higher productivity, and enhanced dependability are among the benefits of cellular manufacturing in LM, according to (Piercy and Rich, 2015). Decreased energy usage, less material usage, and reduced pollution/waste are all advantages of cellular manufacturing. Shorter set-up times and fewer product changes result in lower energy and resource use (Fliedner, 2008). Mitrofanov and Burbridge were the first to propose the concept of Group Technology. Mitrofanov and Burbridge were the first to define cellular manufacturing, which is based on the notion of grouping similar parts to increase output. Customers nowadays want high-quality goods with a wide range of manufacturing needs, as well as small-lot deliveries with short lead times. Manufacturers have responded by implementing efforts such as setup time reduction, cellular production, and quality enhancement in response to these needs. Smaller batch sizes necessitate more frequent setups. As a result, cellular manufacturing is becoming increasingly required in order to service clients in a timely and profitable manner (Piercy and Rich, 2015). The application of Lean Manufacturing principles to cellular manufacturing results in highly adaptable production systems. Separating single activities and uniformly distributing them is a key precondition for enabling flow. Naturally, this is easier for assembly activities, because volume fluctuations may be accommodated with less effort by assigning the needed number of workers. The use of various levels of automation in conjunction with the separation of task contents. Cellular manufacturing is therefore a plant method for increasing physical productivity, which may be measured in units per work hour. Cellular manufacturing systems, according to (Greene and Sadowski, 1983), provide several benefits over a work shop. To name a few, decreased material handling, decreased set-up time, decreased tooling, decreased in-process inventory, decreased flow time, greater operator experience, and enhanced human interactions are just a few examples.

3) With existing suppliers, develop lean economic sustainability

There has been an emphasis on the importance of the supply system in lean production in contemporary industry (Lamming, 1993; Lamming and Hampson (1996)). Because component suppliers have traditionally played a big part in the manufacturing value of a car, this is a natural emphasis in the automobile sector. The early Japanese methods to lean supply originated from a basic need for parts for final assembly and manufacturing via outsourcing. For the Japanese automobile sector, relationship management has become a critical component of securing supply and retaining a competitive edge in both domestic and foreign markets.

Develop lean economic sustainability while considering the influence of existing suppliers on physical productivity

Rather than recruiting new established lean suppliers, the organization benefits more generally by implementing lean to current local suppliers (Fliedner, 2008, Piercy and Rich, 2015). Customers that are lean impose a lot of expectations on their suppliers, and they want them to be dependable in terms of pricing, quality, and delivery (MacDuffie and Helper, 1997). Vertical integration, switching from a non-lean to a lean supplier, or developing the lean capabilities of current suppliers are the only three possibilities for a lean client that wants to assure buying from lean suppliers. Switching to a lean supplier comes with substantial transaction costs, as well as a loss of goodwill from the removed provider and other suppliers watching the event. Because of their likely strong connections with other consumers, finding new lean suppliers is difficult. In many markets, competitive forces are insufficient to develop a ready pool of lean providers (MacDuffie and Helper, 1997; Lamming, 1993). The final solution is to enhance your own lean suppliers' lean manufacturing techniques. To be effective, this necessitates a hands-on approach within the confines of a well-established and collaborative partnership (Lamming, 1993; Lamming and Hampson, 1996; Handfield et al., 2000).

4) Document created in collaboration with the provider

In a lean supply system, the buyer's resident engineer is likely to be present in the manufacturing facility and accessible to handle problems. A significant portion of the supplier's secret cost and production data is shared. The assembler and the supplier collaborate on every element of the supplier's manufacturing process, looking for cost-cutting and quality-improvement opportunities (Womack et al., 1990; Lamming, 1993). The open communication and standardization of all things, including the state of a supplier's connection with the primary assembler, are hallmarks of a lean supply relationship. Suppliers are kept informed about their relationship status at all times and given the chance to improve – opportunism and a refusal to improve on the part of the supplier is punished with a reduction in or loss of business. The supply chain must be coordinated for lean manufacturing to succeed. The structure of the supplier connection has an influence on supply chain coordination. As a result, the corporation may influence the supplier's productivity improvement and decrease the likelihood of part shortages, while also increasing its own productivity. To boost profitability and ensure consistent quality, the organization may produce better products at reduced costs. (Piercy and Rich, 2015)

5) Appropriate supplier performance monitoring

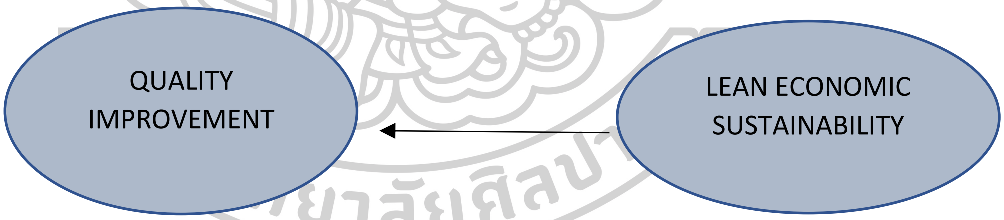
Any effort undertaken by a buyer to improve a supplier's performance and/or capabilities is referred to as supplier development. (Handfield et al., 2000; Krause et al., 2000). Supplier growth necessitates the involvement of financial, capital, and human resources, as well as the sharing of timely and sensitive information. Supplier development techniques are increasingly being employed by customers to enhance their suppliers' manufacturing performance. (Krause et al., 2000). Inter-firm interactions are critical for successful supply management (particularly lean supply) and enhancing supplier performance (Handfield et al., 2000; Scannell et al., 2000). Established and emergent theories give various explanations for the most significant aspects underlying a successful inter-firm connection when one firm's influence is necessary to enhance or assure a process, product, or service. The form of the inter-firm connection and the targeted objective of any improvement endeavor account for most of this diversity (Cousins and Stanwix, 2001; Handfield and Bechtel, 2002; Dyer and Chu, 2003). Supplier development to increase performance.

Physical productivity is impacted by appropriate supplier performance monitoring.

Vendors have a direct (both positive and negative) impact on pricing, quality, technologies, delivery, flexibility, and profits, among other facets of a buying firm's business strategy. (Handfield and Nichols, 1999; Krause et al., 2000). Collaboration or compliance are two methods for establishing and maintaining a supply relationship. Trust, in particular, acts as a foundation for collaboration, whereas power acts as a vehicle for compliance (Handfield and Nichols, 1999; Lamming, 1993). The literature on supply relationships differs on whether establishing a governance structure that minimizes opportunism or trust between the supplier and the buyer (or non-contractual forms of transaction) is more important for a customer's success in achieving desired business outcomes from its supply base. However, all points of view agree that success involves information exchange and a shared commitment to performance improvement, which must be regulated in some way with adequate protections. Anything less is vulnerable to opportunism, putting you at risk of hefty transaction costs (Williamson, 1975; Heide and Stump, 1995). In recent years, the existence of supplier-customer connections that fit neither the "market" nor the "hierarchy" categories has gotten a lot of attention, especially among Japanese firms. Several scholars see a general tendency in customer-supplier interactions toward closer, more cooperative connections as an attempt to mimic the competitive methods of Japanese automakers (Heide and Stump, 1995; Cousins and Stanwix, 2001). Much of the research on Japanese cooperative supply partnerships is predicated on the notion that they are formed to improve some element of supplier manufacturing performance (Liker and Wu, 2000; Scannell et al., 2000).

2. Improving the standard of living

According to (Piercy and Rich, 2015), the benefits of quality improvement in LM include the potential to produce good products at a cheaper cost, hence increasing profitability, and ensuring that customers receive consistent quality, which is an advantage in terms of economic sustainability. In the product quality concept, there are nine lean economic sustainability methods that result in good financial results, including: 1) Keeping an eye on supplier quality, 2) To accomplish the economic aim, suppliers must be trained, 3) Provide suppliers with incentives, 4) QI is a methodology for improving the quality of a process, 5) FMEA is a quality improvement methodology that uses the FMEA approach, 6) SPC quality improvement methodology - QI method, 7) DOE quality improvement methodology - QI methodology, 8) Cause and effect or affinity diagram is a QI approach, and 9) Create a culture of excellence (see Figure 15 and Table 32)



Figures 15 Lean Economic Sustainability on quality improvement principle

Tables 32 Practices for Improving Quality

No.	Dimension	Practices
1.	Product Quality	Keeping an eye on supplier quality.
2.	Product Quality	To accomplish the economic aim, suppliers training
3.	Product Quality	Provide suppliers with incentives.
4.	Product Quality	Quality management processes are being improved.
5.	Product Quality	FMEA is a methodology for improving quality.
6.	Product Quality	SPC is a methodology for improving quality.
7.	Product Quality	DOE's strategy for improving quality.
8.	Product Quality	Affinity diagram or cause and effect diagram.
9.	Product Quality	Create a culture of excellence.

1) Monitoring supplier quality improvement

A long-term cooperative effort between a client and a supplier firm to increase a supplier's technical, quality, delivery, and cost capabilities is known as supplier development (Scannell (Krause et al., 2000) . According to the literature, the major actions employed by buying firms to enhance supplier performance include: assessing a supplier's operations and performance; giving incentives for the supplier to improve; and promoting competition among suppliers (Krause et al., 2000, Handfield and Bechtel, 2002).

2) To reach the economic goal, suppliers must undergo training

Lean manufacturing necessitates a supplier relationship that fosters high levels of learning motivation and trust. The ideal technique of the lean client to assure lean supply is to improve the lean capabilities of current suppliers. High levels of information exchange and training, quick performance gains in suppliers, minimal transaction costs, and working directly with suppliers through training and education define well-developed lean supply arrangements. (Krause et al., 2000, Handfield and Bechtel, 2002, Lamming and Hampson, 1996).

3) Provide incentives to suppliers

Supplier evaluation and incentives are critical facilitators of supplier development (Handfield and Nichols, 1999). Supplier incentives encourage suppliers to improve by providing the message that more business and preferred status for future business is rewarded for better performance. Supplier evaluation enables purchasing firms to examine a supplier's performance, compare it to that of other suppliers, and give guidance to providers in order to achieve improvement goals. Supplier incentives and supplier evaluations have an indirect impact on performance improvement, but direct engagement activities such as the buying firm's training of supplier employees have a direct and crucial role in attaining significant performance improvement (Krause (Krause et al., 2000) et al., 2000). Direct participation operations, in which the buying firm actively participates in the supplier development effort, entail investments by the purchasing firm in the supplier, such as training and education of the supplier's people. Because such efforts reflect transaction-specific investments in the supplier by the buying firm, a direct involvement approach demands special attention (Williamson, 1975). Because the purchasing firm must absorb the costs of direct engagement, the activity exposes the purchasing firm to the risk of unrecoverable transaction expenses if the supply relationship ends prematurely. Finally, the organization provides incentives to suppliers that have an influence on product quality from the manufacturing process (defect unit) in order to get trustworthy components quality from them. 2015 (Piercy and Rich, 2015).

4) Process management, FMEA, SPC, DOE, Cause and effect or affinity diagram are all examples of quality improvement techniques

Process management, failure mode and effect analysis (FMEA), SPC, design of experiments (DOE), and QFD are examples of quality improvement methodologies (Poksinska et al., 2010, Pettersen, 2009). According to several writers (Dahlgaard and Mi Dahlgaard-Park, 2006, Klefsjo et al., 2006) , these techniques are all derived from Japanese TQM methods and have the same root. Businesses of all types are being forced to constantly strive for quality improvement and more efficient and effective ways of managing company operations as a result of the rising competitive difficulties they face. A wide range of control and improvement actions may be utilized to improve quality. categorize the activities into methods, systems, tools, and techniques to create a hierarchical framework. Each strategy is built on a set of key ideas such as customer focus, process control, and process improvement. The use of methods necessitates a strategic decision by top management and resources in terms of staff training and recruiting. A system consists of written instructions and procedures that are used to command and control any type of operation. All of the methodologies, including TQM and Six Sigma, require a quality management system (Dale et al., 2007). A differentiation between a quality management tool, such as a Pareto chart, cause and effect diagram, or affinity diagram, and a methodology, such as statistical process control (SPC) or quality function deployment, is provided by Dale and McQuater (1998). (QFD). According to them, a "tool" is a basic stand-alone program, but a "method" is a more thoroughly integrated approach to issue resolution that may rely on several supporting tools. Charts, histograms, capability assessments, and other tools are included in SPC. To utilize the strategies effectively, further contemplation, skill, knowledge, and training are required. Tools and procedures can be utilized on their own or as part of a larger quality improvement strategy. TQM, Six Sigma, and lean production methodologies all share many tools and methodologies.

5) Create a culture of excellence

Quality Improvement Basics ideas, according to the organization must build a culture of quality in corporate practice. A company's organization, processes, and procedures should all support and embrace QI efforts. The culture of a practice—its attitudes, habits, and actions—reflects the practice team's dedication to excellence. Every practice's QI culture is distinct, but it may involve things like forming specialized QI teams, conducting frequent QI meetings, or setting rules around firm QI goals. To begin, identify and prioritize possible improvement areas. The second step is to gather and evaluate data. Data collection and analysis are at the heart of quality improvement. The information will aid the organization in determining how well its systems function, finding areas that might be improved, setting quantifiable targets, and tracking the efficacy of change. Before starting a QI project, it's critical to gather baseline data, commit to frequent data collection, thoroughly examine the outcomes during the project, and make decisions based on corporate analysis. The next step is to convey the findings. Staff, physicians, and patients must all be aware of quality improvement activities. When designing and conducting QI projects, include the whole practice team and patients, and make sure everyone is aware of the project's needs, priorities, activities, and outcomes. Celebrate and recognize the success of a project after it is completed. Fourth, make a commitment to continuous review. It's a don't ever process to improve quality. A well-run practice will aim to enhance its results on a regular basis, evaluate treatment efficacy, and gather patient and staff feedback on a regular basis. Finally, to disseminate the good news. Share what you've learned with others to encourage widespread, quick progress that benefits everyone.

2.17 Sustainability Performance

Production and consumption that are unsustainable, particularly in developed countries, are the primary causes of environmental degradation. To achieve sustainable development, changes in industrial processes, the types and quantities of resources used, waste treatment, emissions management, and the products produced will all be required. One of the challenges in determining the company's level of sustainability is determining which change paths contribute to sustainability. As a result, relevant measures must be used to facilitate these analyses.

Many studies have focused on sustainable production, offering indicators that might be used as strategic measures for measuring a company's sustainability level and identifying more sustainable solutions for the future. They make it possible to compress a significant amount of data into a format that is easier to manage, compare, and comprehend. Many indicators are centered on the environmental aspects of long-term production. However, in order to accomplish long-term production, a corporation must also consider social and economic aspects (Krajnc et al., 2003).

Indicators can be used in a variety of ways. They condense vast volumes of data from several sources into a format that is easier to comprehend, compare, and manipulate. Companies can utilize indicators to create goals and track their progress.

Setting targets for the indicators itself makes interpretation easier. These goals assist the decision-maker in visualizing which actions should be prioritized in the future. Numerous definitions of indicators can be found in the literature (Karassin and Series, 2012, Ingold et al., 2000). However, stating the primary role of indicators is more useful. Gallopı´n (1997) identifies the following major functions of indicators: 1) evaluating current circumstances and movement in respect to targets and objectives, 2) Reflecting the status of a system, 3) Providing early warning statistics, 4) Predicting future conditions and trends, 5) Comparing across locations and situations Highlighting what is happening in a large system.

Through the use of sustainable production indicators, more sustainable choices could be identified. (Azapagic et al., 2000): 1) Product comparisons across companies, 2) Process comparisons between companies manufacturing the same product, 3) Unit benchmarking within enterprises 4) A company's rating in comparison to other companies in its industry 5) Measuring a sector's progress toward long-term growth.

Several groups are now working on developing a set of metrics to track a company's progress toward sustainability. (Veleva and Ellenbecker, 2001) have analyzed 1) International Organization for Standardization (ISO14031), 2) Global Reporting Initiative (GRI), 3) World Business Council for Sustainable Development (WBCSD), and 4) Center for Waste Reduction Technologies are four of the most well-known indicator frameworks (CWRT).

The findings show that the majority of indicator frameworks are still in development, and none of them can be used to evaluate sustainable production as a whole. Social indicators, in contrast to environmental indicators, receive the least emphasis in existing indicator systems. There is a trend toward adopting a small number of straightforward and easy-to-apply indicators (between 10 and twenty). Indicators can be used individually or in theme groupings to show connections between issues and to investigate the causes of trends (Executive, 2002).

The variety of indicators and measures being generated in this rapidly expanding subject demonstrates the relevance of conceptual and methodological work in this sector. (Bennett et al., 2013).

Despite evidence that it is impossible to create sustainability indicators that are applicable to each company or organization, a variety of standardization approaches have been offered thus far. However, introducing a quantitative measure of sustainable production is a challenge because some components of sustainability (particularly the social aspect) cannot be quantified. expressed. There are no challenges with some issues, such as energy use and water use, because these are similar to all businesses. More specific indicators, on the other hand, must be defined separately, depending on the industry.

Some specialists have recently attempted to introduce fuzzy set theory and construct fuzzy mathematical models to assess long-term progress. The combinatorial character of the fuzzy rules poses a possible challenge in the actual implementation of the fuzzy model using approximation reasoning. For example, utilizing two linguistic values (e.g. acceptable and unacceptable) to analyze the contribution of n sustainability indicators to sustainable development yields a fuzzy rule base of 2n rules. As a result, for only ten indicators, we have 1,024 rules. The fuzzy rule base quickly becomes opaque and difficult to apply as the number of fuzzy rules grows rapidly (Cornelissen et al., 2001).

The concept of a sustainable process index (SPI) was proposed based on a set of sustainability requirements and traditional mass and energy balances (Galilei, 2004). The SPI compares mass and energy flows caused by human activities to natural flows, measuring the potential impact (pressure) of processes on the ecosphere. Because natural flows are constantly related to area (for example, biomass growth, precipitation, and, most significantly, solar radiation), the SPI's basic unit is area. The lower the space need for a certain activity, the smaller the environmental effect of that activity. However, in order to deal with the complexities of sustainability-related challenges for various systems, indicators must reflect the system as a whole as well as the interactions of its subsystems. Their goal is to demonstrate how well the system is performing, and they are very reliant on the type of system they are monitoring (Afgan and da Graça Carvalho, 2000).

It is suggested that a corporation start with simple, easy-to-implement compliance and resource efficiency indicators before moving on to more sophisticated indicators that cover supply-chain, societal consequences, and lifecycle implications. Using indicators of sustainable production is one step in a continuous improvement process aimed at transitioning the organization from using primarily low-level indicators to using all levels of sustainable production indicators. (Veleva and Ellenbecker, 2001).

Therefore, the summary of Sustainability Indicators frameworks designed to drive sustainability pertaining to production. In this research the selection of framework considering if it should directly applicable at factory level and focus on measuring shop floor, production managers and available of a suitable set of indicators for measuring sustainability progress and the indicators are comparable between factories.

2.18 Production Indicators for Long-Term Sustainability (SPIs)

Firms, governments, and the general public have increasingly focused on measuring techniques to analyze the environmental elements of sustainability during the last ten years. While there are various lists of environmental performance metrics (for example, ISO 14301 from the International Organization for Standardization, the Global Reporting Initiative, and the World Business Council for Sustainable Development), these lists provide little guidance on how businesses can improve the indicators they currently use to better measure sustainability. The University of Massachusetts Lowell's Lowell Center for Sustainable Production has created a tool that allows businesses to assess the efficiency of sustainability indicator systems. The tool contains a five-level framework for classifying current indicators in relation to the fundamental principles of sustainability.

Standard financial indicators have long been used by businesses to measure their success. Only recently have an increasing number of businesses began to employ environmental, health, and safety (EHS) as well as social metrics (e.g., 3M, Shell, Amoco, Interface). Despite the fact that the number of sustainability indicators in the literature is expanding, none of them contributes to our knowledge of corporate sustainability. Companies fail to address important environmental and social implications, according to a new analysis of fifty company sustainability reports (Tseng et al., 2009).

In 1992, the United Nations Conference on Environment and Development introduced the notion of sustainable production, which is closely tied to the notion of sustainable development. The conference determined that the unsustainable pattern of consumption and production, particularly in developed countries, is the primary cause of the global environment's continuous degradation (Weiss, 1992). Sustainable production is linked to firms and organizations that manufacture things or provide services, whereas sustainable consumption is focused on consumers.

The suggested technique is based on an indicator framework established at the University of Massachusetts Lowell's Lowell Center for Sustainable Production (LCSP) and described in an earlier study (Veleva et al., 2001). Sustainable production, according to the LCSP, is the production of goods and services through non-polluting methods and systems that save energy and natural resources, are economically viable, are safe and healthy for employees, community, and customers, and are socially and creatively satisfying for all workers (Production, 1998). Because it stresses environmental, social, and economic dimensions of firms' actions, this definition is congruent with contemporary understanding of sustainable development. It is also more practical, as it emphasizes six key areas of sustainable production: energy and material utilization (resources) the natural world (sinks) workers, and goods that promote social justice and community development.

Companies that want to improve their everyday activities by being more sustainable should focus on each of these six elements. Risk should not be shifted from one part of sustainable production to another. The LCSP has developed nine guiding principles to help businesses better understand sustainable production. These concepts serve as the foundation for the current indicator structure. These principles address concerns such as product and packaging design, waste and incompatible byproduct removal, work-related hazard minimization, and continual improvement of worker and community well-being and development (Quinn et al., 1998) . These ideas are frequently reflected in a company's mission and goals. Companies that want to make their everyday activities more sustainable can set objectives and targets based on the LCSP principles and track their progress using indicators of sustainable production.

Tables 33 Sustainable manufacturing principles (reproduced with permission from the Lowell Center for Sustainable Production)

1. Throughout their life cycles, products and packaging are meant to be safe and environmentally friendly; services are meant to be safe and environmentally friendly.
2. Wastes and environmentally unfriendly byproducts are constantly minimized, eliminated, or recycled.
3. Energy and resources are saved, and the forms of energy and materials employed are the most suitable for the goals.
4. Hazardous chemical substances, physical agents, technology, and work methods are continually minimized or eliminated.
5. Workplaces are designed to reduce or eliminate risks in the areas of physical, chemical, biological, and ergonomics.
6. Management is dedicated to an open, participatory process of continuous review and development that is centered on the firm's long-term economic success.
7. Work is planned in such a way that it conserves and enhances employee efficiency and creativity.
8. All workers' safety and well-being, as well as the further development of their abilities and skills, are top priorities.
9. Communities in and around workplaces are valued and improved economically, socially, culturally, and physically, and justice and fairness are fostered.

2.19 Frameworks for Sustainability Indicators

The following is an overview of the Sustainability Indicators frameworks aimed to drive production sustainability. In this study, the framework was chosen with the goal of being directly relevant at the factory level, with an emphasis on assessing the shop floor, production managers, and the availability of a sufficient set of indicators for assessing sustainability development that are comparable across factories.

(Azapagic et al., 2000)

A framework based on a lifecycle approach with a strong environmental focus was presented. Their indicator list was very evenly spread throughout the three dimensions, with an ecological indicator preponderance (46 percent). The analytical hierarchy method (AHP) was suggested by (Fan et al., 2010b) to understand how to analyze the value of various indicators on sustainability. They utilized a set of 32 indicators organized into six main aspect groups, with just 16% relating to the economic component.

(Veleva and Ellenbecker, 2001)

The research by is the most cited paper on SPIs (Veleva and Ellenbecker, 2001)**.** Their proposed approach is based on the Lowell Center for Sustainable Production's indicator framework (1998). Energy and material usage, natural environment, social justice and community development, economic performance, labor, and goods are the six fundamental characteristics of SP that are changed from the three sustainability dimensions. There are 22 SPIs in all, which are divided into five tiers, each of which is described as evolving. Each indication is thoroughly discussed and divided into one of five categories, all of which are associated with sustainability goals. The indicators are created with the goal of being quantifiable in mind; each indication has a distinct unit, kind, and measurement time.

(Krajnc et al., 2003)

Indicators of sustainable production are presented for analyzing and increasing company sustainability. It begins by outlining the key principles of such production as well as a set of requirements that businesses must meet in order to be sustainable. It begins by identifying the key functions of indicators before moving on to the role of indicators.

(Labuschagne et al., 2005)

The framework for operational sustainability suggested by (Labuschagne et al., 2005). There are no economic restrictions because there is a strong focus on corporate responsibility policies (Pham Duc, 2012). Overall equipment efficiency (OEE), manufacturing lead time from point of inquiry, on-time delivery, and gross value added were the four performance indicators offered. As a result, they're all concentrating on the economic aspect of sustainability (Joung et al., 2013) In line with NIST's indicator classification, GRI, Dow Jones, the United Nations, and the National Institute of Standards and Technology (NIST) analyzed sets of SPIs and categorized them in five categories to analyze a company's manufacturing operations. (Joung et al., 2013) defined the five dimensions but did not provide any indication lists. Instead, they pointed to NIST's list of 212 indicators, 25 percent of which were related to economic development and performance management.

(Tseng et al., 2009)

Interdependencies amongst sustainability criteria were examined, and a fuzzy asset theory for analyzing SPI uncertainty was presented. They employed the AHP to enhance decision-making in complicated topics by selecting characteristics and criteria suggested by (Veleva and Ellenbecker, 2001). In a case study, the capacity to frame sustainability decisions was put to the test.

(Paju et al., 2010)

Developing a sustainable manufacturing mapping strategy using value stream mapping. The notion of fostering sustainability at the level of the industrial system through the introduction of approaches that managers are already familiar with and using them in a slightly different way to assess sustainability is intriguing.

(Samuel et al., 2013)

A case study evaluating sustainability at five distinct enterprises in Malaysia's petrochemical industry was presented. Additional indicators from the GRI (2014) criteria were included to the framework of the Lowell Center for SP (VelevaandEllenbecker, 2001). Only two economic indicators were chosen out of a total of 42. Samuel et al. (2013) examined the extent to which these indicators were tracked at the case study firms in order to determine sustainability. Their findings revealed that two-thirds of the indicators were tracked across the board. (Veleva and Ellenbecker, 2001) also offered a case study on the adoption of SPIs at a rubber industry. The list of indicators examined, on the other hand, is mostly global or national in scope, with the bulk of indicators falling under the environmental and social aspects.

(Fan et al., 2010b)

"A study of metrics for assessing the sustainability of manufacturing" Indicators of sustainable manufacturing in industry and academics. While the notion of sustainable manufacturing has been discussed for some time, there has been no clarity on how to define or assess it, particularly in the economic and social dimensions. This study aims to look at the present condition of sustainable indicators in U.S. manufacturing organizations, as well as examine diverse academic perspectives on how to weight economic and social indicators using the Analytic Hierarchy Process (AHP). The study finishes with a review of statistical findings as well as suggestions for additional research and application.

(Moneim et al., 2013)

A worldwide SPI was developed as a weighted index based on 18 unique environmental, economic, and social parameters. The economics dimension includes metrics such as added value, faulty product ratios, and product diversifications. They put the framework to the test at a small printing and packaging firm.

(GRI, 2014)

Its goal is to become a widely acknowledged framework for reporting a company's economic, environmental, and social performance. Their guidelines place a significant emphasis on reporting and include a large number of indicators divided into three categories: economic (four aspects), environmental (12 aspects), and social (six aspects) (30aspectsinfoursubcategories). As a result, it should be underlined that the GRI reporting criteria do not adequately represent economic sustainability. In reality, the majority of the factors (90%) fall under the environmental and social dimensions.

(Winroth, 2016)

Only a few of the suggested Sustainable Performance Indicators have direct factory application. The hypothesis is that if a proper set of indicators for gauging sustainability were accessible, shop floor awareness and improvement of sustainability would improve. This is a set of appropriate indicators that is proposed with the goal of measuring development while also being comparable amongst manufacturers. The goal of this framework is to come up with a set of useful performance metrics for a production manager. Methodology/approach/design This study offers a two-step study, the first of which is a literature study with the goal of collecting a comprehensive list of sustainability indicators applicable on the shop floor. The importance of this list for production managers will be discussed in the second phase.

A questionnaire study of Swedish small and medium-sized firms (SMEs) is conducted. Conclusions According to the results of the poll, 27 of the 52 proposed indicators were statistically significant, and another 20 were endorsed by at least 50% of the respondents. 16 of the 47 indicators are related to the environmental dimension, 18 to the economic dimension, and 13 to the social dimension. As a result, there is a reasonably decent distribution across the three sustainability aspects, and the number of relevant indicators has been significantly increased, particularly in the economic dimension, when compared to the list of indicators contained in previous frameworks. Companies looking for relevant metrics to promote sustainability changes may find this set of indicators useful. Originality and worth This study take a different approach to SP by focusing on shop floor production, which a production manager may impact.

The investigation of indicators for measuring sustainable manufacturing, which two out of eleven studies of sustainability indicator framework are the most suitable to the study that can apply to the focus area on lean manufacturing in the automotive field, which is at the factory level and similar attention to focus on measuring shop floor and production manager, is the most suitable to the study that can apply to the focus area on lean manufacturing in the automotive field, which is at the factory level and similar attention to focus on measuring shop floor and production manager.

The first indication is SPIs, which are a collection of appropriate indicators that seek to assess progress while also being comparable amongst factories, according to the empirical study of (Winroth, 2016) The second indication is GRI, or the Global Reporting Initiative (Fan et al., 2010a), which is often recognized as the most important endeavor in assessing a company's long-term viability (see Table 34).

Tables 34 The Sustainability Indicators

Dimensions	Items	Indicate how much of the following your company does:	SPIs	GRIs
Environment	1	Your business makes good use of the land.	* 1	
Environment	2	Your firm is working to limit the amount of freshwater it uses.	* 2	* EM6
Environment	3	Your firm is working to minimize energy use.	* 3	* EM5
Environment	4	Your business is working to improve the amount of recycled/reused water.		* EM7
Environment	5	Your organization is working to minimize energy use in the manufacturing process.		* EM3
Environment	6	Your organization is working to decrease the amount of energy lost by equipment that are idle.	* 4	
Environment	7	Your firm is working to boost the usage of renewable energy sources.	* 5	* EM4
Environment	8	Your business is working to minimize the amount of materials needed per unit of output.	* 6	* EM1
Environment	9	Your firm is taking steps to decrease material waste.	* 7	
Environment	10	Your business is working to decrease the amount of material lost throughout the production process.	* 8	* EM1
Environment	11	Your firm is working to increase the amount of material that is reused or recycled.	* 9	* EM2
Environment	12	Your firm is working to minimize the amount of packaging it uses.	* 10	
Environment	13	Based on manufacturing technologies, such as cutting fluids and mold lubricants, your organization is working to decrease the quantity of material added in the production process.	* 11	

Environment	14	Before recycling, your organization is working to limit the quantity of waste created (air, water, and land).	* 12	* NE3,4
Environment	15	Your organization is taking steps to limit the quantity of hazardous trash it generates.	* 13	* NE5
Environment	16	Reduced greenhouse gas emissions are a priority for your firm.	* 14	* NE1
Environment	17	Your business is working to decrease environmental incidents.	* 15	
Environment	18	Your organization is taking steps to cut EHS compliance expenditures.	* 16	
Economic	19	Your organization is working to enhance value addition per employee, which is calculated as revenue minus the cost of acquired goods and services per employee.	* 17	
Economic	20	Your firm is working to enhance the labor-to-revenue ratio (employment cost in relation to sales).	* 18	
Economic	21	Your company's pay expense per hour is reasonable.	* 19	
Economic	22	Your firm has a solid average salary level.	* 20	
Economic	23	Your firm is working to grow its consumer base.	* 21	
Economic	24	Your business is taking steps to lessen the quantity of consumer complaints.	* 22	
Economic	25	Your business can improve the amount of new clients it receives each year.	* 23	
Economic	26	Your firm is working to boost the rate at which new goods are introduced.	* 24	
Economic	27	Your company's R&D budget can be increased.	* 25	
Economic	28	Your business is working to improve overall equipment efficiency (OEE).	* 26	
Economic	29	Your company's productivity can be improved (production pace).	* 27	
Economic	30	Your firm is working to improve manual labor performance rate, which is the ratio of actual to typical speed for a manual work assignment.	* 28	
Economic	31	Your firm is working to improve delivery accuracy.	* 29	
Economic	32	Your firm is working to cut down on manufacturing lead times.	* 30	
Economic	33	Your firm is working to cut down on maintenance hours.	* 31	
Economic	34	Your firm is working to expand its supplier base.	* 32	
Economic	35	Stops caused by suppliers might be reduced by your organization.	* 33	
Economic	36	Your firm is working to increase the percentage of suppliers that do not have EHS infractions.		* EP1
Economic	37	Your firm has activities to Invest in Environmental Protection		* EP2
Economic	38	Your firm has action to Invest in local suppliers		* EP3
Economic	39	Your organization is keeping track of the expenditures of EHS		* EP4

		compliance.		
Economic	40	Stakeholders can assess and participate in your firm.		* EP5
Economic	41	Your business is working to enhance items that can be disassembled, reused, or recycled.		* P1
Economic	42	Your firm is working to boost the percentage of items bearing an environmental label.		* P2
Economic	43	Your firm is tracking the percentage of items having take-back policies.		* P3
Economic	44	Your firm has actions to enhance customer Satisfaction		* P4
Social	45	Your company's compliance with general warning and safety labeling standards		* P5
Social	46	Your business is working to decrease the number of accidents and incidents.	* 34	
Social	47	Your organization is taking steps to decrease employee absences due to work-related accidents or illnesses.	* 35	* W1
Social	48	Your organization is working to improve the amount of hours of training per employee.	* 36	* W2
Social	49	Your firm is working to raise educational levels through formal schooling or on-the-job training.	* 37	
Social	50	Your firm is working to minimize the number of temporary employees.	* 38	
Social	51	Your organization is taking steps to improve employee happiness.	* 39	* W3
Social	52	Your organization is working to improve the male-to-female ratio.	* 40	* W5
Social	53	Employees engaging in systematic improvement efforts at your firm have activity to share.	* 41	
Social	54	Your organization is working to expand the number of cross-functional improvement teams.	* 42	
Social	55	Your organization is working to limit the number of new employees it hires each year.	* 43	
Social	56	Your business is taking steps to decrease employee turnover.	* 44	* W4
Social	57	Your organization is taking steps to boost employee support for physical exercise, health care, and medications.	* 45	
Social	58	Your business engages in community expenditures and charitable giving.		* CS1
Social	59	Your business has a variety of community-business collaborations.		* CS2
Social	60	Your business is working to increase the percentage of items consumed locally.		* CS3
Social	61	Your firm has calculated the pay gap between the corporate		* CS4

		wage and the local minimum wage.		
Social	62	Your business is investing in human rights provisions.		* CS5

2.20 Chapter Summary

This chapter reviews the literature on lean manufacturing ideas and criteria, lean social, lean economic, and lean environment sustainability practices and sustainability, sustainability principles and metrics, sustainability performance, and research gaps.

CHAPTER 3
RESEARCH METHODLOGY

3.1 Introduction

Jankowicz, (2002) defined a research method is a method for collecting and analyzing data in order to extract knowledge from it that is systematic and ordered. Research methods, on the other hand, are defined by (Frankel et al., 2006) as "all those procedures/techniques employed for doing research, such as research questionnaires, analytical tools, and so on". On the contrary, research methodology could be understood as an approach for systematically solving a research problem that not only discusses research methodologies but also addresses the logic behind the methods. The previous chapter went over the relevant literature, found gaps, and concluded with the research goal and concerns. The research methods and process for the thesis are discussed and determined in this chapter. The chapter starts with a comparison of quantitative and qualitative research methods. The following is the rationale for employing a quantitative technique to achieve the study goals. The preparation of the questionnaire and the data gathering process are then discussed. This chapter goes through the study instrument, types of questions utilized, survey population, sample size determination, and data handling in detail. Before the conclusion of this chapter, ethical considerations are considered.

3.2 Research Process

Overall, the goal of this thesis is to establish a theoretical framework for the new knowledge and the partitional to firms that arise during the methodology's implementation. A research methodology is a method for solving an issue in a systematic fashion. It's a branch of science that looks into how research should be carried out. The techniques by which researchers go about their business of describing, comprehending, and forecasting events are known as research technique. It can also be defined as the study of knowledge acquisition strategies. Its purpose is to provide a research work schedule. This chapter's fundamental structure is provided by the definition, which is divided into the following sections:

Four hypotheses have been developed by which to investigate lean sustainability and sustainability performance in firms. In order to understand the effect of lean sustainability to sustainability performance. Hypothesis have been developed, as follows:

H1: Lean Social Sustainability has a positive impact on social sustainability performance.

H2: Lean Economic Sustainability has a positive impact on economic sustainability performance.

H3: Lean Environment Sustainability has a positive impact on environment sustainability performance.

H4: Lean Sustainability has a positive impact on sustainability performance.

The following section, titled Fundamental Philosophical Assumptions, discusses three well-known epistemological methods to inquiry. The most relevant epistemology is chosen depending on its relevance to the current study. In the Research Design section, you'll find a list of some of the most popular quantitative and qualitative research approaches. Each methodology is described in full, along with an assessment of its merits and drawbacks, as well as its suitability for this study. The selection and extensive study of the most appropriate methodology for this research finishes this part.

3.2.1 Fundamental Philosophical Assumptions

Creswell and Creswell, 2017 In any kind of work or study, it is important to always bring a certain set of beliefs as well as philosophical assumptions.

According to (Falconer and Mackay, 1999) , before beginning any research project, it is critical that the researcher understands respective philosophies and approaches to the problem phenomenon being studied. This is significant since it aids the researcher in developing a research approach. This section looks at epistemology and how it affects academic research. Epistemology is the philosophy of knowledge. Knowing and being are assumed to be separate in epistemology. Philosophers have diverse ideas on what knowing is. A researcher must be able to defend his or her own point of view (Doyle et al., 2009). "Positivist," "interpretive," and "critical" are the three epistemological categories. Understanding the research approach of each epistemological category and adopting a research approach that generates required knowledge are necessary for better research (Easterby-Smith et al., 1997).

1. Positivism

“A significant fundamental concept emerges from the study of the growth of social intelligence in all directions and across all times: each area of our knowledge passes successively by means of three theoretical conditions: theological, or fictional; philosophical, or abstract; and scientific, or positive (Comte, 1975). According to (Morgan, 1979) positivism is defined as the search for relationships between the constituent elements in order to understand and anticipate occurrences. “Positivists see reality as a combination of observable features that exist independently of the researcher and his or her instruments.”(Easterby-Smith et al., 1997).

Positivists also believe that the world is organized around fixed correlations between occurrences, and that their role as researchers is to examine these unstructured links using structured methods. The positivist philosophy focuses the research findings' objectivity, reproducibility, and generalizability (Chen and Hirschheim, 2004).

The idea of objectivism is connected with the positivist philosophy; researchers who follow this method primarily use objectivity to evaluate the world. This attitude is also used in association with a qualitative approach. Furthermore, this attitude necessitates that the researcher do research with a big sample size, and so the data gathering process is based on highly organized, large samples.

This ideology is linked to the concept of objectivism; researchers who follow this method primarily use objectivity to evaluate the world (Cooper and Schindler, 2006). This mindset is primarily utilized in conjunction with a quantitative method. Furthermore, this mindset necessitates the researcher conducting study with a big sample size, as well as a well structured data collection approach, large samples, measurement, and a quantitative method are preferred, while a qualitative approach can be utilized as well; the researcher's own beliefs have no bearing on or influence over the research (Saunders and Lewis, 2012). The positivist philosophy emphasizes scientific procedure, statistical analysis, and generalization of data in order to establish or refute a concept. Furthermore, scholars in this stance are attempting to explain rather than comprehend occurrences (Mack, 2010).

2. Interpretive

Interpretive studies, on the other hand, consider reality to be socially produced and given meaning by humans, rather than objective and external. The interpretive researcher argues that by evaluating these meanings in their natural environments, they can better understand the topic under investigation (Fahy, 1995). According to The focus of interpretive studies is on observation and narration (Silverman, 1998). Interpretive studies rarely generalize their findings to a larger population; instead, they prefer to use their in-depth knowledge of the phenomenon to inform other circumstances (Orlikowski and Baroudi, 1991, Chen and Hirschheim, 2004).

3. Critical

Current social systems, according to critical academics, have a long history and are regularly repeated by people. They acknowledge that, while individuals can take actions to improve their socioeconomic circumstances, the social, political, and cultural forces that oppose them often limit their ability to do so (Hammersley, 1995). The basic goal of critical research is to investigate and publicize the deep-seated oppositions and conflicts that exist in contemporary social practice in order to replace them with alternative social structures that will diminish and eradicate these alienating and temporary social situations (Orlikowski and Baroudi, 1991, Falconer and Mackay, 1999).

4. Select Philosophy

Because of the nature of this study, which is primarily concerned with forecasting situations by looking for connections between the two variables of lean manufacturing and sustainability performance. The information can be utilized to search for cause-and-effect links and, as a result, to make predictions. “Positivists see reality as a collection of observable features that exist independently of the researcher and his or her instruments." in that sense, the research philosophy is positivism.

3.2.2 Research approach

The two basic methodologies that researchers might employ to conduct research are deductive and inductive. The use of a deductive or inductive method to theory is a crucial issue when choosing an approach. When a theory and hypothesis are developed, a deductive approach is used, and the research plan is constructed to test the hypothesis. The deductive method is primarily linked with quantitative approaches, whereas the inductive method is primarily linked with qualitative approaches. According to (Cavana et al., 2001), In the deductive approach, the researcher begins by constructing a theory, then formulates hypotheses, then gathers and analyzes data, and lastly accepts or rejects the hypotheses, resulting in empirical evidence of specific phenomena. The researcher begins by observing phenomena, then analyzes a pattern and themes, formulates a relationship, and lastly builds a theory using the inductive methodology. An inductive process requires conducting research, gathering data, and formulating a hypothesis as a data analysis.

The contrasts between deductive and inductive reasoning are discussed. (Saunders et al., 2007),p.127 The deductive technique has been discovered to be a highly structured strategy that is based on scientific principles and a requirement to explain the link between variables. The researcher must be self-sufficient, and the researcher must choose an acceptable sample size in order to generalize the research findings. When doing research in this study, deductive methodologies were examined in order to fulfill the research objectives.(Saunders et al., 2003) observe that "The deductive approach relates more to positivism, while the inductive approach relates more to interpretivism," says the author.

3.2.3 Research Strategy

A distinct type of research strategy is one in which the researcher selects the best strategy or strategies to assist them in answering the research questions and achieving the research goal (Saunders and Lewis, 2009). Surveys, case studies, experiments, action research, grounded theory, and archival research are some of the research methods used pointed out a number of factors that affect the choice of research strategies (Saunders and Lewis, 2009). The most important thing is to choose the appropriate tactics to assist the researcher in answering the research questions and achieving the study's objectives. The researcher's ideology, research approach, and study purpose should all be reflected in the strategy (or strategies). Other criteria, including the level of info available to the researcher, time and critical data availability, and the accessibility of potential participants, may also influence the study strategy selection (Yin, 2003).

However, three elements influence the differentiation of strategies: (1) the sort of research questions; (2) the degree of control over events; and (3) the study focus, whether historical or current events.

This study focuses due to the exploratory and descriptive nature of this study, the researcher chose to conduct a survey. The researcher's goal is to improve knowledge of the current condition LM in sustainability context in terms of knowing their current practices, which may have relationship to sustainability performance.

1. Survey

In the world of business and management, a survey is one of the most widely utilized tactics. A survey can assist in determining who, what, where, how many, and how much. (Yin, 2003). The quantitative method and the deductive approach are related in a survey strategy. Although there are other strategies such as organized observation and structured interview, the questionnaire is the most common form of data collecting for the survey approach. A survey's main advantage is that it allows the researcher to generalize the findings for the least amount of money possible. Another benefit of the survey is that after the data is collected, the researcher will be self-sufficient. Unlike other tactics that rely on other aspects and information, once the data is collected, the researcher will be free to evaluate it in order to answer the research questions and achieve the research's main goal (Saunders and Lewis, 2009, Burns and Groove, 2014, Beins, 2017).

However, there are some limitations and weaknesses of survey. When compared to alternative tactics, such as case studies, the survey's outcome could be weak (Remenyi and Williams, 1995). (Robson, 1993) says that this tactic may not be the best way to collect data, especially when it comes to presenting real-world accounts.

According to a study performed by (Orlikowski and Baroudi, 1991) in this field, quantitative surveys are the most common study method. Quantitative surveys use preset questionnaire material to reveal data on respondents' views, opinions, and experiences. Furthermore, when gathering data, survey methods are well-known for their rapid respondent turnover (Creswell and Creswell, 2017). This strategy has been chosen in this study to understand the lean sustainability practices and the sustainability performance in MNCs in Thailand .

3.2.4 Research Method

For researchers, there are a variety of research approaches to choose from. However, when to employ them is determined by their strengths, shortcomings, and relevance to the research. The truth value and application of the study are the foundations of research evaluation, whether qualitative or quantitative. The value of truth is related to the design's honesty as well as the methods utilized to collect and weigh facts. The relevance and significance of the findings in experimental practice is referred to as applicability. Two simple questions make up the investigative assessment: (1) Is this a prominent area of research? (2) Is the study design suitable for addressing the study question? The nature of the research question should be reflected in the study design. . (Pickler, 2007) Which research approaches and procedures are appropriate for acquiring knowledge about phenomena are determined by the basic procedural assumptions (Orlikowski and Baroudi, 1991). There are various types of research methodologies, but the most common distinction is between qualitative and quantitative approaches (Mingers, 2003), which are explained in the next section.

3.2.4.1 Qualitative versus Quantitative research methods

There is a significant distinction between qualitative and quantitative analysis. Qualitative research entails a thorough investigation of a variable or phenomenon. Quantitative analysis, on the other hand, focuses on describing a phenomenon across a greater number of participants, allowing for the summarization of characteristics across groups or individuals (Beins, 2017, Burns and Groove, 2014). Qualitative research is defined as "a methodology used to get an understanding of underlying causes, opinions, and motivations" in research. It gives information about the problem or aids in the development of concepts or hypotheses for quantitative research.

Wyse (2011) defines quantitative research as a technique to quantifying an issue by generating numerical data or information that can be turned into usable statistics, which is the polar opposite of the description above. It's used to quantify things like attitudes, views, and actions, among other things.

The ability of a qualitative method to generalize results from a broader sample group is its distinguishing feature. In quantitative research, measurable data is used to form facts and identify patterns. Qualitative analysis, as defined by its goals, is defined as an in-depth, thorough understanding in which the analyst must participate as an active participant. Quantitative analysis, on the other hand, tends to be focused and structured since we, as analysts, must play the role of objective investigators (Burns and Groove, 2014, Wyse, 2011).

3.2.4.2 Selected research methodology

Selected research methodology for this thesis for this study, it is decided to use the quantitative research process using survey questionnaires. The reason is that the focus of this research is on the effect of lean sustainability practices in different functional areas on sustainability performance of manufacturing firms. This is a query that aims to confirm a theory by asking "how and what." During data collection, the approaches will be very structured and consistent, utilizing a questionnaire with closed-ended questions. The findings will provide numerical data that can be statistically examined, demonstrating a link between lean sustainability methods and a company's sustainability performance. This study problem would be best served by quantitative technique. A quantitative methodology makes it possible to examine the relationship among many variables of lean sustainability and sustainability performance. The information can be utilized to search for cause-and-effect links and, as a result, to make predictions.

3.2.5 Time Horizon

The study's time horizon is significantly reliant on the study's goal. Longitudinal and cross-sectional time horizon studies are the two forms of time horizon research. If the goal of the study is to find something over time, such as the evolution of manufacturing industries, a longitudinal study is the ideal option; if the goal is to provide a snapshot, a cross-section is the ideal option. Employee surveys are frequently used by researchers in cross-sectional studies. (Robson, 2002). Because the goal of this study is to get a snapshot of current practices in Thailand's automotive industries, a cross-sectional methodology is appropriate. The switch to a cross-sectional study was not made at random; it was made because there was no previous information on the relationship between lean sustainability and firm sustainability performance in Thailand had improved overtime. According to (Bouma et al., 1995), p. 114) in a longitudinal study, the researcher must inquire, "Has there been any change over time?" This is not possible in this instance.

3.2.6 Techniques and procedures

By identifying the study questions, the researcher is attempting to answer them which the factors influence sustainability performance and what lean sustainability practices are positive relationship of sustainability performance . To do so, you'll need to figure out the best way to collect the data you'll need. In the business and management industry, many types of data collecting techniques are employed, such as questionnaires, structured interviews, and structured observation (quantitative data collection), while analysis is done using quantitative graphing and statistical analysis numerical data. This research applied closed-ended questionnaire, as the main technique for collecting the required data to answer the research questions and meet the objectives of the research.

3.3 Sampling Technique

According to (Carroll and Johnson, 1990), the sample frame is determined by the study questions and research objectives. (Gunter, 2013) stated that after identifying the target demographic, the researcher needs use a good technique to categorize the sample. Researchers might choose between two types of sampling techniques: probability sampling (representative) and non-probability sampling (judgmental).

Probability sampling implies that the entire population has an equal chance of being chosen, but non-probability sampling is employed when acquiring or including the entire sample is challenging, resulting in a sample that does not represent the entire population. Choosing between these two methodologies is heavily influenced by resource availability and population accessibility; additional criteria that influence the choice include whether the research requires face-to-face interaction with participants and whether The population is concentrated geographically. (Burns and Groove, 2014, Beins, 2017).

Non-probability sampling includes five different techniques: quota, purposive, snowball, self-selection, and convenience. Under the heading of probability sampling, there are five ways to choose from: simple random, systematic, stratified random, cluster, and multi-stage are all examples of randomness (Burns and Groove, 2014, Beins, 2017).

This study used non-probability sampling with purposive strategies, based on the aforementioned descriptions and distinctions between methodologies.

3.3.1 Purposive sampling

Purposive sampling can be useful for researchers in specific situations, such as when they're trying to: 1. Choose one-of-a-kind situations that are particularly instructive; 2. Identify individuals of a hard-to-reach, specialized demographic; or 3. Identify certain types of instances that require further (Neuman and approaches, 1997).

Although some writers claim that a non-probability sample can be skewed and cannot be generalized in most circumstances, the results of this study can still be generalized and representative because they were drawn from a population inside Thailand's registered industries. Purposive sampling entails the researcher attempting to locate the most appropriate sample for the research and the one that will best aid in the achievement of the research's aims; consequently, the samples utilized in this technique may be representative of the population. According to (Parasuraman et al., 2006, Kumar, 1976) Purposive sampling approaches come in handy when researchers are trying to piece together a historical reality, explain a phenomenon, or produce something about which little is known. Purposive sampling enables the researcher to select cases that will best answer the research questions and will help the researcher fulfill the research objectives. (Burns and Groove, 2014, Beins, 2017).

The population frame for this study is obtained from Thai Autoparts Manufacturers Association (TAPMA) directory 2020. The list of manufacturing firms consists of electrical, electronic, metal, plastic, rubber and other automotive components. The manufacturing firms type involved in this study were separated from Thai owner 100 percent, Foreign owner 100 percent and Thai &Foreign owners. The population of this study consists of all manufacturing firms who implement lean manufacturing in Thailand automotive for tier 1 and tier 2 suppliers 710 auto part makers and 1,700 supporting companies. In total sample population are 2,400 companies (boi.go.th). Tier 1 suppliers are companies that supplier parts or systems directly to OEMs (Original Equipment Manufacturers). These suppliers usually work with a variety of car companies, but they're often tightly coupled with one or two OEMs, and have more of an arms-length relationship with other OEMs. Many firms supply parts that wind up in cars, even though these firms themselves do not sell directly to OEMs. These firms are called Tier 2 suppliers. Tire 2 suppliers are often experts in their specific domain, but they also support a lot of non-automotive customers and so they don't have the ability or desire to produce automotive-grade parts.

Purposive techniques were employed to make sure that the selected sample fitted the research criteria, which is that the industries had to be automotive manufacturing firms with have main focus on environmental outcomes identify by quality system certification obtain in their firm at least ISO 9001 and ISO14001 or ISO26000 or OHSAS 18001or ISO45001.This study combines issues related to sustainability focusing on lean social sustainability aspect with operational aspect of the level of lean implementation. So, the most appropriate respondents are key informants who hold managerial position in manufacturing firms.

3.4 Data collection and analysis

To gather the essential data for this investigation, numerous primary and secondary data sources (primary and secondary) were utilized. A survey of automotive manufacturing firms, was used for the primary data using questionnaire technique as well as a literature review (secondary data). Several techniques, such as pilot testing and the index of item objective, were used to ensure the research's credibility and validity. The index of item objective congruence of expert opinions on the final results must be in agreement in order for the data to be as reliable and valid as feasible. The sections below explain how the data were collected and analyzed.

3.4.1 Questionnaire

The questionnaire is a frequently used and useful tool for gathering survey data. It provides organized, often numerical data, may be presented without the presence of the researcher, and is often relatively simple to evaluate. For descriptive or explanatory research projects, questionnaire approaches are commonly used. The questionnaire is useful in descriptive research because it allows researchers to learn about people's attitudes, opinions, and organizational practices. Self-administered questionnaires, structured interviews, and telephone questionnaires are examples of different types of questionnaires. If the objective of the research is to be descriptive in business and management studies, the researcher must give the questionnaire to a sample that is typical of the population (Stone, 1993, Gillham, 2008, Krosnick, 2018)

Five-item Likert scales were utilized in the surveys to determine the extent to which the automobile manufacturers were involved, as well as to establish accurate and trustworthy numeric findings for statistical analysis. The following five-likert scales were chosen to allow participants to choose the most appropriate rating for their current situation: (1), Strongly Disagree (2), Disagree (3), Neutral (4) Agree (5); Strongly Agree. The data was entered into SPSS software to generate various analyses, such as Cronbach's alpha, descriptive analysis, and independent sample t-test. Cronbach's alpha is a test for internal consistency and reliability. This test is crucial, and the researcher must ensure that there is internal consistency before proceeding with the analysis; a value above 0.7 is considered to be acceptable (Pallant and Manual, 2010).

Before conducting further statistical analyses such as t-tests or correlations, descriptive analysis is recommended since it helps to validate that the researcher has not violated the assumption. It was utilized in this study to gather data in order to describe the sample. (Pallant and Manual, 2010). It's also used to collect and summarize the information gathered; this exam aids in the organization of respondents' responses into statistical data so that the frequency of responses can be shown. (Coakes, 2005).

To assess if there was a significant difference between groups, an independent sample t-test was employed to compare the mean scores of two different groups, late response group, between firms of different sizes, such as small and medium-sized firms, and ownership structure such as Thai and foreign owners, and Thai owner firm. This test revealed whether the two groups have statistically significant differences in mean score, allowing the hypothesis to be tested. (Pallant and Manual, 2010).

3.5 Reliability

Participants' error or bias, as well as observer error or bias, can all affect the research's dependability (Robson, 2002). Researchers can utilize Cronbach's alpha, the most often used method for checking internal reliability, to check the dependability of their study (Awang, 2012, Samuels, 2017). In addition, pilot testing could enhance reliability (Abu-Hussin, 2010).

Cronbach's alpha was utilized in this study to assess the overall reliability of each construct's measurement scale, as well as to check the findings' dependability and ensure that the instrument employed in the study was reliable. Cronbach's alpha is a mathematical approximation of the proportions of total variance, which represents the scale's dependability. (Oppenheim and measurement, 1992) A figure above 0.7 is regarded reliable and sufficient when the alpha value is determined from the 1-0 value. Furthermore, in order to improve the reliability, the researcher ran a pilot study to avoid respondents' misinterpretation (Awang, 2012, Samuels, 2017, Blackmon et al., 2005). When compared to the qualitative method, the quantitative method has a better possibility of gaining reliability. (Blackmon et al., 2005).

3.6 Validity

The content validity of a construct is a key step in its evaluation. (Garver and Mentzer, 1999) because it ensures that the issue under investigation is well covered (Srivastava and Rego, 2011). To obtain content validity, the researcher must conduct a thorough examination of the current literature in order to develop scale items that can represent the entire topic. The researcher made effort to cover as much literature as possible in order to assure validity; also, the researcher did a pilot test prior to the study's actual conduct. The majority of the items in both the qualitative and quantitative methods were produced based on the work and recommendations of other researchers (Sadeghian et al., 2010).

Predictive and concurrent validity are the two types of criterion validity. Concurrent validity reflects the current situation, while predictive validity demonstrates the success of the measuring device (Srivastava and Rego, 2011). One of the most influential researchers in the development of measuring theory and practice is construct validity. It establishes a link between psychometric concepts and practices and theoretical concepts." Researchers should think about using numerous data sources, building a chain of evidence, and having key informants review a draft case study report to verify construct validity. (Srivastava and Rego, 2011, Yin, 2003).

In this study, the instruments employed have content validity because they were developed after a thorough examination of the literature and the questionnaire was piloted. Moreover, following the recommendation by (Yin, 2003) that there should not be a reliance on a single source of data. In addition, the questionnaire summarizing the overall findings of submitting the report to an expert panel to see if the findings match the realities of lean sustainability.

3.6.1 Specialist opinion

According to Oxford (dictionaries, 2014) “A person who is exceptionally knowledgeable about or skilled in a certain area,” or “having or involving a great deal of knowledge or skill in a particular area,” is how an specialist is defined. The purpose of incorporating an specialist panel's opinion and knowledge is to increase the trustworthiness of the research findings, which will improve the robustness of the outcome while also guiding the research. (Achanga, 2007). The specialists should be well-versed on the topic being addressed and discussed in the study. (A Fink, 1984).

Specialists in the field, as well as those who have published studies on sustainability manufacturing, were sought out by the researcher, and key personnel from Thailand institutions who are specialist in the field, since (Achanga, 2007) experts, it is said, must be informed (having studied or worked) and current in the field of study.

Index of item objective congruence was sent to five specialists in the academic field of lean and sustainability. The Item Objective Congruence (IOC) Index is the foundation for determining item quality. Specialists are asked to assign a content validity score to each of the following items: If the specialist is confident that this item accurately measured the attribute, the score is 1. If the specialist is certain that this item does not measure the attribute, the score is –1. If the specialist is unsure if the item measures or does not measure the desired attribute, the score is 0. The IOC of the qualified items should be equal to or greater than 0.50. From total list of questions in this study 149 items. There are 108 questions that their average scores of IOC are equal to or greater than 0.50 reserved. There are 41 questions that the average scores of IOC is lower than 0.5 considered as disqualified. The researcher use the result of IOC to be one of the criteria to review the result after the response sample and conduct the statistical analysis.

3.6.2 Questionnaire pretesting

The survey was given to 30 automotive employee samples that were similar to the target group for the questionnaire of Tier 1’s automotive part manufacturer in Chonburi specific position of supervisor or above working in manufacturing areas. The pretest in this study followed the guideline of giving the questionnaire to the pilot participants in the same way that it would be given to the main study participants (Peat, 2002).

The guideline including, seek comments from the audience to assist in the identification of any ambiguities or challenging queries, Ensure that the time required to complete the survey is appropriate. Remove any questions that are superfluous, difficult, or confusing. Determine whether each question has a sufficient range of responses, and that responses can be interpreted in terms of the information needed, check that all questions are answered correctly, rewrite and amend any questions that were not answered correctly, and incorporate the feedback from the pilot research participants; if necessary, shorten, revise, and, if possible, pilot again.

In determining the research directions, the pretest result and feedback were crucial. The following are some of the comments and suggestions: 1) The questions contained jargon and sophisticated phrases with ambiguity; non-lean enterprises would not be able to understand them; therefore, such inquiries should only be asked of lean organizations; and 2) there were way too many questions, which could result in a lower response rate or a lack of credibility in the replies; 3) the researcher agreed with the pilot test ideas and thought they were quite valid.

The result of Pre-Test from 30 samples presents the reliability. The Cronbach's Alpha value is used in this study to determine the items' dependability. Therefore, Kerlinger and Lee (2000) proposed that the Cronbach's Alpha value should be 0.5 or higher for valid internal dependability. (Samuels, 2017, Hooper and Zhou, 2007, Yap et al., 2018) . Cronbach's Alpha of 0.6 or higher is recommended as a credible indicator of internal consistency, while a value of 0.70 indicates that the tool met the research's high quality standards. As a result, shows the good internal consistency as a critical in the research direction to conduct the study survey.

Tables 35 Reliability Cronbach's Alpha of Lean Sustainability (n=30) Pre-Test

Variable	Items	Cronbach's Alpha	Internal Consistency
Lean Social Sustainability	25	0.957	Good
1. Work Force	14	0.927	Good
2. Information Transparency	5	0.882	Good
3. Community contribution	6	0.924	Good
Lean Economic Sustainability	14	0.932	Good
1. Physical Productivity	5	0.851	Good
2. Product Quality	9	0.909	Good
Lean Environment Sustainability	49	0.984	Good
1. Waste Reduction	18	0.955	Good
2. Process Centered focus	15	0.978	Good
3. High people involvement and participation	16	0.942	Good
Sustainability Performance	68	0.974	Good
1. Social Sustainability Performance	18	0.910	Good
2. Economic Sustainability Performance	26	0.928	Good
3. Environment Sustainability Performance	18	0.956	Good

3.7 Response rate

The response rate is calculated as the number of valid questionnaires divided by the total number of questionnaires delivered; in other words, the number of valid questionnaires divided by the number of useable questionnaires (Fink, 1995). There is no consensus among academics as to what the appropriate response rate percentage is or what is considered acceptable (Baruch, 1999). A lower response rate could jeopardize the study's credibility (Bowling, 2005).

People do not respond for a variety of reasons, including the respondent's refusal to engage or the fact that he or she has not received the questionnaire (Baruch, 1999). The researcher is unable to change the first reason, even though this study attempted to persuade respondents by emphasizing the value of their involvement (Bowling, 2005). Other factors that reduce response rates, such as the researcher's inability to contact respondents or communication hurdles. As a result, before to administering the questionnaire, the researcher must be aware of specific parameters. To improve response rates, the researcher can schedule his or her visit at a convenient time and avoid vacations (Bech, 2009). Furthermore, researchers can avoid a low response rate by properly planning ahead of time for the survey, which can easily overcome a low response rate by selecting the most appropriate period (Bech, 2009).

A questionnaire can be used in a variety of methods, including postal mail, electronic mail, online surveys, and phone interviews and distributing in person. The response rate to mail surveys is poor (Baruch, 1999). The reason for the low response rate to email and telephone surveys, and it could be attributed to a variety of factors, including lack of anonymity, formal image, reward, and cosmetic aspects (Ranchhod, 2001).

To boost response rates, the author used a variety of strategies, including attaching a letter from SUIC (written by the study's supervisor) with the official university logo, describing the study's motivations over the phone and in the attached letter; ensuring respondent identity and confidentiality; providing respondents with a copy of the identified results, which may assist them in improving their process; employing an adequate font size, a clear style, and straightforward wording to make the questionnaire understandable; Attempting to keep the questionnaire as brief as feasible; and avoiding delivering the questionnaire by email without first phoning the respondents (to avoid wasting time).

3.8 Ethical considerations

According to (Merriam, 1998), during the data collection process, ethical considerations arise. Ethics is inextricably tied to the integrity of the subject matter and research in management and social science disciplines. (Bryman, 2006). In qualitative research, ethical difficulties are likely to arise in the gathering of data and distribution of findings (Merriam, 1998). This is closely tied to the integrity of the research and the topic matter in social science or management research. (Bryman, 2006).

To prevent ethical issues, the researcher must first come to an agreement before collecting data. The participants were issued a cover letter detailing the motivations and goal of the research study, and they were told that their names and companies would be kept secret and treated with in a strictly discreet manner. Furthermore, the researcher reminded participants that they could leave at any time and without giving a reason.

Before conduct the questionnaire pretest, the researcher obtained the certificate of human research ethics training and was approved the research protocol for ethical review from the research institute Silpakorn University International college.

3.9 Chapter summary

This research used deductive approach. The quantitative method was adopted; the forms of validity used were expert panel and pretest. The technique was considered in this research was survey questionnaire. The research philosophy, approach, methodological choice, strategy, and finally the techniques and procedures utilized for data collecting and data analysis have all been reviewed and presented in this chapter in order to support the choice of each process in the research. This chapter also covered the methods used to improve the validity and response rate of the survey.

CHAPTER 4
FINDINGS

4.1 Introduction

The objective of this study is to develop the measurement scale of lean social sustainability, lean economic sustainability and lean environment sustainability dimensions. This research also aims to examine the effects of lean social sustainability, lean economic sustainability and lean environment sustainability on sustainability performances. First, a preliminary analysis of the collected data is performed, including the response rate and sample group. Second, the results of the descriptive statistics of the respondents ‘profile are reported. Third, the description of variables is shown. Finally, the results of hypotheses testing, respectively.

4.2 Descriptive Statistical Analysis of Respondent Personal Data

Out of 2,400 Tier 1 and Tier 2 companies, purposive techniques to send out questionnaire to 600 companies for the firms located nearby Bangkok for convenience following up including the province of Bangkok, Ayuthaya, Samutprakarn, Chonburi, Pathumthani, Rayong, and Prachinburi. The ‘MNCs firm’ here refers to companies as well as individual units or sites within the companies. The total response as per sample for proportions as 410 a representative sample, however the final receive is 406 questionnaire both by email and return paper questionnaires that the appropriate sample size for SEM analysis (Guadagnoli and Velicer, 1988, Molwus et al., 2013), and the proper criterion that Lomax and Schumacker (Schumacker and Lomax, 2016) indicated for the sample size is between 250-500. Cochran (1977) developed a formula to calculate a representative sample for proportions as

$$n_0 = \frac{z^2 pq}{e^2}$$

n = 410 (Rounded)

where, 0 n is the sample size, z is the selected critical value of desired confidence level, p is the estimated proportion of an attribute that is present in the population, q = 1− p and e is the desired level of precision

The sample data is separated in this study so that exploratory and confirmatory factor analysis can be performed. The first 100 samples were utilized for exploratory factor analysis, with the remaining 306 samples being utilized for confirmation factor analysis. We must first do EFA to uncover the underlying components of a construct, according to (Worthington and Whittaker, 2006, Cabrera-Nguyen and Research, 2010). After the EFA has been completed and the underlying factors have been identified, the factor structures will be subjected to Confirmatory Factor Analysis (CFA) using the Structural Equation Modeling approach. CFA must be run on a different set of sample respondents in order to evaluate if the items of scale kept in the EFA genuinely suit the data, or what we call "Model Fit." Through this, we may evaluate if the scale items are valid and reliable.

The sample of this research is the employees in automotive firms who work in different areas. The completed questionnaires were returned 406 copies, equivalent to a 68 percent response rate. The statistical analysis of sample personal data, as shown in table 36. The results of the analysis of personal status data of the employee in automotive firms in Thailand. Demographic data collected compost with company year of establishment, quality system certification, type of company, number of employees, job position, gender, age, and years of working. The majority of respondents worked in the firm establish.

The majority of respondents worked for the firm establishing between 1994-1998 (36.9 percent), 2001-2014 (22.4 percent), 1982-1990 (22.2 percent), and 1964-1977 (18.5 percent) respectively, and when considering the quality system certification of their firms, it is found that most are (1) ISO9001 and ISO14001 and OHAS18001 and IATF16949 (33.5 percent), (2) ISO9001 and ISO14001 and IATF16949 (26.6 percent), (3) ISO9001 and ISO14001 (21.7 percent), (4) ISO9001 and ISO14001 and ISO45001 and IATF16949 (7.4 percent), (5) ISO9001 and ISO14001 and TS16949 (3.9 percent)(6) ISO 9001 (3.2 percent), (7) ISO9001 and ISO14001 and OHAS18001 and ISO5001 and ISO45001 and ISO/IEC17025 and

TLS8001 (3.7 percent) respectively. Most of respondent worked in foreign owner (37.2 percent), Thai and foreign owners (36.9 percent), and Thai owner firm (25.9 percent). In term of size of firm, most of respondents work in the firm having employee more than 200 person (96.3 percent), follow by 51-200 person (3.7 percent). In term of job position, most of respondents were manager (31.8 percent), office worker (25.1 percent), shop floor worker (22.7 percent), supervisor (20.2 percent), and director (0.2 percent) respectively. In term of gender shown that male are (68.5 percent), and female (31.5 percent). The majority of respondents were between 36-40 years old (28.6 percent), 41-45 years old (22.4 percent), 31-35 years old (20 percent), 26-30 years old (18 percent), 46-50 years old (4.9 percent), 51-55 years old (4.9 percent), and 20-25 years old (1 percent) respectively. In terms of year of working, most are between 6-10 years (47.3 percent), between 1-5 years (27.6 percent), between16-20 years (15.8 percent), between 11-15 years (3.2 percent, between 21-30 years (3.2 percent), and above 30 years (3 percent) respectively.

Tables 36 Summary of Respondent Personal data

No	Topic	Personal Status	Frequency	Percentage
1	Company year of establishment	1964-1977	75	18.5
		1982-1990	90	22.2
		1994-1998	150	36.9
		2001-2014	91	22.4
2	Quality System Certification	ISO 9001	13	3.2
		ISO 9001, ISO14001	88	21.7
		ISO 9001, ISO14001, IATF16949:2016	108	26.6
		ISO 9001, ISO14001, ISO45001,	30	7.4
		ISO 9001,	15	3.7
		ISO 9001, ISO14001,OHAS18001,	136	33.5
		ISO 9001, ISO14001,TS16949	16	3.9
3	Type of company	Foreign owner 100%	151	37.2
		Thai owner 100%	105	25.9
		Thai and Foreign owners	150	36.9
4	Number of employee	51-200 person	15	3.7
		More than 200 person	391	96.3
5	Job position	Director	1	0.2
		Manager	129	31.8
		Supervisor	82	20.2
		Shop floor worker	92	22.7
		Office worker	102	25.1
6	Gender	Male	278	68.5
		Female	128	31.5
7	Age	20-25 years	4	1.0
		26-30 years	73	18.0
		31-35 years	81	20.0
		36-40 years	116	28.6
		41-45 years	91	22.4
		46-50 years	20	4.9
		51-55 years	20	4.9
		above 65 years	1	0.2
8	Year of working	1-5 years	112	27.6
		6-10 years	192	47.3
		11-15 years	13	3.2
		16-20 years	64	15.8
		21-30 years	13	3.2
		above 30 years	12	3.0

4.3 Summary results of descriptive analysis of lean sustainability upon variables in the total frame work

The purpose of this section is to present the primary statistical analysis of lean sustainability practices upon concerned variables of all factors in the lean sustainability frame work, consisting of the mean score, standard deviation (SD), Skewness, Kurtosis, and interpreted level of practice. The analytical results are proposed as follows.

Tables 37 Descriptive table (n=406)

Variables	Items	Mean	SD	Ske.	Kur.	Level of mean
Lean Social Sustainability	25	4.164	0.439	-0.784	0.598	High
1. Work Force	14	4.165	0.481	-0.443	-0.106	High
2. Information Transparency	5	4.154	0.593	-0.696	0.446	High
3. Community contribution	6	4.168	0.581	-0.700	0.358	High
Lean Economic Sustainability	14	4.072	0.510	-0.640	-0.353	High
1. Physical Productivity	5	3.998	0.569	-0.292	-0.500	High
2. Product Quality	9	4.113	0.563	-0.783	-0.065	High
Lean Environment Sustainability	49	4.150	0.412	-0.939	1.229	High
1. Waste Reduction	18	4.138	0.475	-0.812	0.523	High
2. Process Centered focus	15	4.141	0.461	-0.606	-0.104	High
3. High level of people involvement and participation	16	4.171	0.486	-1.014	1.811	High
Sustainability Performance	61	4.036	0.473	-1.023	0.812	High
Social Sustainability Performance	17	4.002	0.507	-1.083	1.592	High
Economic Sustainability Performance	26	4.013	0.510	-0.730	0.028	High
Environment Sustainability Performance	18	4.108	0.543	-0.836	0.268	High

Score Interval (Mean) Evaluation Criteria : 1.00 – 1.79 Very low level,1.80 – 2.59 Low level, 2.60 – 3.39 Medium level, 3.40 – 4.19 High level, 4.20 – 5.00 Very high level (Tantekin Çelik and Oral, 2016). According to Table 37, overall, lean social sustainability was perceived at an agree level. There were three variables appraised as agree namely work force, information transparency, and community contribution. Overall, lean economic sustainability was perceived at an agree level. There were two variables appraised as agree namely physical productivity, and product quality. Overall, lean environment sustainability was perceived at an agree level. There were three variables appraised as agree namely waste reduction, process centered focus, and high level of people involvement and participation. Overall, sustainability performance was perceived at an agree level. There were three dimensions appraised as agree namely social sustainability performance, economic sustainability performance, and environment sustainability performance. The result shows that the skewness and kurtosis values of all constructs met the normality assumption of SEM. Thus, all data are appropriate for confirmatory factor analysis discussed in the next section.

4.4 Non-response bias

The non-respondent bias can be assessed by comparing the responses from early and last waves, such as the first and last quarterly of responses (Armstrong & Overton, 1977). In this study, there were 29 sample, 7.14 % of total sample of n= 406, considering as Non-respondents who response late, comparing with the rest of first 377 questionnaires. Those 29 samples were distinguished according to the following up more than one time and delay from the first group response for more than two weeks. The Chi-Square tests was used for comparing the demographic difference from the value of Pearson Chi-Square. For a Chi-square test, a p-value that is less than or equal to the significance level indicates there is sufficient evidence to conclude that the observed distribution is not the same as the expected distribution. Since the p-value is lower than the significance level (α = 0.05), we fail to reject the null hypothesis.

The comparison from two groups the results found there were no demographic information different violated significantly from number of employees, gender, age, and year of working.

Tables 38 Demographic comparison of Non-response bias – Non significant items

Descriptive		**Response**			**Pearson Chi-Square**		
	Details	Early	Late	total	Value	df	Asymp Sig. (2-sided
Gender	Male	261	17	278	1.404[a]	1	0.236
	Female	116	12	128			
Employee	51-200	15	0	15	1.198[a]	1	0.274
	above 200	362	29	391			
Age	20 - 25	4	0	4	5.976[a]	7	0.543
	26 - 30	66	7	73			
	31 - 35	76	5	81			
	36 -40	106	10	116			
	41 - 45	87	4	91			
	46 - 50	20	0	20			
	51 - 55	17	3	20			
	> 65	1	0	1			
Year of Work	1-5	105	7	112	7.555[a]	5	0.183
	6-10	179	13	192			
	11-15	10	3	13			
	16 - 20	58	6	64			
	21 - 30	13	0	13			
	> 30	12	0	12			

Independent group t-test analysis comparing between early and late replies

As suggested by (Zou et al., 1997) , Proper comparison of responding and non-responding firms was not possible due to a lack of reliable data from the non-responding firms. To compare early and late responses, we employed the wave analysis method using the data's t-test as the next best approach (replies received after the follow up contacts) as suggested by (Armstrong and Overton, 1977). According to the wave analysis approach, people that react slowly are more likely to be non-respondents (Zou et al., 1997). They recommended utilizing the t-test method under both equal and unequal group variance assumptions. We observed no between-group mean deviations at the 5% level for any of the study's variables in the t-test analysis. As a result, it is possible to infer that non-response bias had no significant impact on this study. (Skarmeas et al., 2002) (see Table 39).

Tables 39 Statistically Significant Differences Between Responses of Early and Late response

Dimension	Group Question	Mean First Response n=377	Mean Late Response n=29	Statistical Significance
Lean Social Sustainability	Work Force	4.1625	4.3072	.118
	Information Transparency	4.1450	4.3678	.052
	Community Contribution	4.1565	4.3103	.170
Lean Economic Sustainability	Physical Productivity	4.0928	4.2414	.296
	Product Quality	4.1017	4.3218	.089
Lean Environment Sustainability	Waste Reduction	4.1658	4.3793	.052
	Process Centered Focus	4.1447	4.2978	.104
	High level of people involvement	4.1612	4.3395	.062
Sustainability Performance	Environment Sustainability Performance	4.1160	4.2978	.079
	Economic Sustainability Performance	4.0006	4.1773	.074
	Social Sustainability Performance	3.9922	4.1360	.141

4.5 **Analysis of Measurement Model and Reliability**

The exploratory factor analysis (EFA) was used to analyzed data specifically for lean sustainability practices and sustainability performance because the observed variables were initially proposed by this study. Thus, they have not been supported by any previous theoretical findings. Meanwhile, CFA performed with all constructs to test whether observed variables acceptably represented their latent construct.

4.5.1 Exploratory factor analysis EFA and Reliability Cronbach's alpha

A pilot survey was conducted, and exploratory factor analysis EFA was used to choose 106 participants as the minimal sample size for the pilot study, as indicated by (Hoque et al., 2017, Hoque and Awang, 2016, Hair et al., 2010) to assess the internal validity of the CA concept and its underlying dimensions The proposals provided by the target population were fully examined by the target population (Salkind, 2010) when administering the instrument for the pilot study.

a. Lean Social Sustainability

EFA was performed with 25 indicators of lean social sustainability by using the principal components method together with the Varimax rotation. Every single indicator was encoded, ranging by abbreviation below (see Table 40), and the results can be seen in Table 41 and 42

Tables 40 Code Representing Lean Social Sustainability practices

No.	Component	Code	Indicator
1.	Work Force	WFS1	Kaizen improve attitudes
2.	Work Force	WFS2	Kaizen find solution of safety
3.	Work Force	WFS3	Standardized work reduce variations
4.	Work Force	WFS4	Standardize work of improve safety
5.	Work Force	WFS5	Standardize work improve plant safe
6.	Work Force	WFS6	Jidoka make problem visualization
7.	Work Force	WFS7	Poka-yoke make problem visualization
8.	Work Force	WFS8	Visual Management improve safety
9.	Work Force	WFS9	5 why engage improve workplace
10.	Work Force	WFS10	5 why increase cross-skill
11.	Work Force	WFS11	Cross functional team engagement
12.	Work Force	WFS12	Shop floor workers continue improve
13.	Work Force	WFS13	Evaluated shop floor
14.	Work Force	WFS14	Compensation establishment to workers
15.	Information Transparency	ITS1	Charitable giving
16.	Information Transparency	ITS2	Transparency to employee
17.	Information Transparency	ITS3	Sustainability audit disclosure
18.	Information Transparency	ITS4	Customer involve in quality program
19.	Information Transparency	ITS5	Transparency to suppliers in costing

20.	Community Contribution	CCS1	Community engagement activity
21.	Community Contribution	CCS2	Employee participate in community
22.	Community Contribution	CCS3	Charity donations
23.	Community Contribution	CCS4	Clear performance metrics of reputation
24.	Community Contribution	CCS5	Supporting in local initiatives
25.	Community Contribution	CCS6	Dedicates to local community

EFA result Lean social sustainability of total 25 questions. The result generated using principal component and Varimax rotation found that 7 questions had cross-loadings greater than 0.40 and 5 questions had factor loadings below 0.40 (Hair, et. al., 2010), as such the decision was made to exclude 12 questions (WFS01, WFS02 WFS04, WFS06, WFS07, WFS12, WFS13, WFS14, CCS01, CCS05, ITS04, ITS05). Finally, remain 13 questions arrange to three grouping for the factors structure where every item had factor loadings above 0.40 with no cross-loadings greater than 0.40. In consequence, the factor structure of lean social sustainability detected by the EFA was composed of six variables for the work force component, four variables for information transparency component, and three variables for community contribution component (See Table 41).

Overall, the construct validity investigated by EFA was satisfactory assured by Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett's test of sphericity values. The KMO of 0.660 demonstrated acceptable sampling sufficiency(Hoque and Awang, 2016, Awang, 2012).

Meanwhile, Bartlett's test of sphericity was significant (0.00), which is less than 0.05 in meeting the required significance value (Hoque et al., 2018, Hoque and Awang, 2016, Awang, 2012). Therefore, the KMO valuation near 1.0 and the Bartlett's test significance near to 0.0 indicate that data is adequate and suitable to continue the reduction process (Hoque and Awang, 2016).The variables thus showed appropriateness for factor structure detection. The total variance explained by the three factors altogether captured 52.161 percent, the percentages of variance characterized by components 1-3 after the rotation was 22.493 percent,17.356 percent, 12.312 percent, respectively.

Tables 41 Exploratory factor analysis Rotated Component Matrix of Lean social sustainability
(n = 106)

	Components		
	Work force	Information Transparency	Community contribution
WFS09	.857		
WFS10	.826		
WFS11	.697		
WFS03	.632		
WFS05	.511		
WFS08	.476		
CCS04		.830	
CCS02		.740	
CCS03		.643	
CCS06		.583	
ITS02			.725
ITS03			.705
ITS01			.680
% of Variance	**22.493**	**17.356**	**12.312**
Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.660, Bartlett's Test of Sphericity = 374.926, p-value = .000			

From EFA result, the new code of lean social sustainability practices can be seen in Table 42.

Tables 42 New Code Representing Lean Social Sustainability practices

No.	Component	Code	Indicator
1.	Work Force	WFS3	Standardized work reduce variations
2.	Work Force	WFS5	Standardize work production improve safety
3.	Work Force	WFS8	Visual Management improve safety
4.	Work Force	WFS9	5 why engage workers improve workplace
5.	Work Force	WFS10	5 why increase cross-skill
6.	Work Force	WFS11	Cross functional team engage employees
7.	Information Transparency	ITS1	Charitable giving
8.	Information Transparency	ITS2	Transparency to employee
9.	Information Transparency	ITS3	Sustainability audit and public disclosure
10.	Community Contribution	CCS2	Employee participate in community
11.	Community Contribution	CCS3	Charity donations
12.	Community Contribution	CCS4	Clear performance metrics of reputation
13.	Community Contribution	CCS6	Dedicates to local community

In the next step, the variables of overall three constructs investigated the reliability Cronbach's alpha. In this study, the Cronbach's Alpha value is used to determine the item's dependability. As a result, Kerlinger and Lee (2000) recommended that the Cronbach's Alpha value should be 0.5 or above for genuine internal reliability (Samuels, 2017, Hooper and Zhou, 2007, Yap et al., 2018) . Cronbach's Alpha of 0.6 or above was proposed as a trustworthy measure of internal consistency, while a result of 0.70 indicated that the instrument met the research's high criterion of quality. Internal consistency of the work force component, which consists of six variable items, was rated as good by Cronbach's Alpha (0.802). The component of Information transparency consist of four variable items was perceived internal consistency at good level of Cronbach's Alpha 0.813. Finally, the component of community contribution consist of three variable items was perceived internal consistency at acceptable level of Cronbach's Alpha 0.762. (See Table 43).

Tables 43 Cronbach's Alpha of Lean social sustainability Component (n=106)

Component	Number of items	Cronbach's Alpha	Internal Consistency
Work force	6	.802	Good
Information Transparency	4	.813	Good
Community contribution	3	.762	Acceptable

b. Lean Economic Sustainability

EFA was performed with 14 indicators of lean economic sustainability by using the principal components method together with the Varimax rotation. Every single indicator was encoded, ranging by abbreviation below (see Table 44), and the results can be seen in Table 45 and 46.

Tables 44 Code Representing Lean Economic Sustainability practices

No.	Component	Code	Indicator
1.	Physical Productivity	PPE1	SMED reduce cost of production
2.	Physical Productivity	PPE2	Cellular manufacturing increase productivity
3.	Physical Productivity	PPE3	Existing supplier's approach
4.	Physical Productivity	PPE4	Collaborative documented with supplier
5.	Physical Productivity	PPE5	Tracking supplier productivity performance
6.	Product Quality	PQE1	Monitoring supplier quality improvement
7.	Product Quality	PQE2	Supplier training to meet economic target
8.	Product Quality	PQE3	Provide incentives to suppliers
9.	Product Quality	PQE4	Process management of quality improve
10.	Product Quality	PQE5	FMEA quality improvement technique
11.	Product Quality	PQE6	SPC quality improvement technique

12.	Product Quality	PQE7	DOE quality improvement technique
13.	Product Quality	PQE8	Cause and effect or affinity diagram
14.	Product Quality	PQE9	Establish quality culture

EFA result Lean Economic sustainability of total 14 questions. The result generated using principal component and Varimax rotation found that 2 questions had cross-loadings greater than 0.40 and no questions had factor loadings below 0.40 (Hair, et. al., 2010), as such the decision was made to exclude 2 questions (PPE02, PPE04). Finally, remain 12 questions arrange to two groupings as below table. As the result of EFA of new grouping questions there are three questions (PQE06, PQE07, PQE08) in product quality dimension which rotated in physical productivity. On the other hand, one question of physical productivity (PPE05) is rotated in product quality dimension.

The dimension of physical productivity, there are five activities and three of them (PQE06, PQE07, PQE08) from product quality are rotated in physical productivity component. According to the literature SPC, DOE and Cause and Effect can contribute not only improve product quality but also productivity of the end process result. (Kimura and Kiyota 2004, Srinivasu, Reddy et al. 2011, Jamil, Khalid et al. 2018). Therefore, these three practices can combine to describe physical productivity as new measurement scale.

The dimension of product quality practices, there are seven activities and one of them (PPE05) from physical productivity is rotated in product quality component. According to the literature The assembler and the supplier work together over every detail of the supplier’s production process, looking for ways to cut costs and improve quality (Womack et al., 1990),(Lamming and Hampson, 1996). In this mention the factory aims to improve supplier in term of cost reduction which positive effect on physical productivity, however not only cut cost is not overall expectation but also product quality needs to be improved. Thus, tracking supplier’s cost-effective solution also reasonable and has positive effect to product quality.

Thus, from EFA result, the new code of lean economic sustainability practices can be seen in Table 46

Tables 45 New Code Representing Lean Economic Sustainability practices

No.	Component	Code	Indicator
1.	Physical Productivity	PPE1	SMED reduce cost of production
2.	Physical Productivity	PPE3	Existing supplier's approach
3.	Physical Productivity	PQE6	SPC quality improvement technique
4.	Physical Productivity	PQE7	DOE quality improvement technique
5.	Physical Productivity	PQE8	Cause and effect or affinity diagram
6.	Product Quality	PPE5	Tracking supplier productivity performance
7.	Product Quality	PQE1	Monitoring supplier quality improvement
8.	Product Quality	PQE2	Supplier training to meet economic target
9.	Product Quality	PQE3	Provide incentives to suppliers
10.	Product Quality	PQE4	Process management of quality improve
11.	Product Quality	PQE5	FMEA quality improvement technique
12.	Product Quality	PQE9	Establish quality culture

Overall, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett's test of sphericity values provided sufficient assurance of the concept validity tested by EFA. The sample sufficiency was shown by the KMO of 0.674 (Hoque and Awang, 2016, Awang, 2012).

Meanwhile, Bartlett's test of sphericity was significant (0.00), which is less than 0.05 in meeting the required significance value (Hoque et al., 2018, Hoque and Awang, 2016, Awang, 2012). As a result, the KMO valuation around 1.0 and the significance of the Bartlett's test near 0.0 suggest that the data is enough and suitable to continue the reduction procedure (Hoque and Awang, 2016).The variables thus showed appropriateness for factor structure detection. The total variance explained by the three factors altogether captured 44.43 percent, the percentages of variance characterized by components 1-2 after the rotation was 22.604 percent, 21.829 percent, respectively.

Tables 46 Exploratory factor analysis Rotated Component Matrix of Lean economic sustainability

	Lean Economic Sustainability	
	Physical Productivity	Product Quality
PQE06	.820	
PQE07	.800	
PQE08	.667	
PPE01	.626	
PPE03	.600	
PQE01		.682
PQE04		.679
PQE03		.640
PQE02		.624
PPE05		.588
PQE09		.511
PQE05		.430
% of Variance	22.604	21.829
Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.674, Bartlett's Test of Sphericity = 337.556, p-value = .000		

In the next step, the variables of overall two constructs investigated the reliability Cronbach's alpha.

The component of physical productivity consist of six variable items was perceived internal consistency at acceptable level of Cronbach's Alpha 0.790. The component of product quality consist of four variable items was perceived internal consistency at good level of Cronbach's Alpha 0.832.

Reliability of component that concluded from 12 questions inform the internal consistency (See Table 47).

Tables 47 Cronbach's Alpha of Lean economic sustainability

Component	Number of items	Cronbach's Alpha	Internal Consistency
Physical Productivity	5	.790	Acceptable
Product Quality	7	.832	Good

c. Lean Environment Sustainability

EFA was performed with 49 indicators of lean environment sustainability by using the principal components method together with the Varimax rotation. Every single indicator was encoded, ranging by abbreviation below (see Table 48), and the results can be seen in Table 49 and 50

Tables 48 Code Representing Lean Environment Sustainability practices

No.	Component	Code	Indicator
1.	Waste Reduction	WRN1	Kaizen practice on environment waste
2.	Waste Reduction	WRN2	5S reduction of waste, waiting, searching
3.	Waste Reduction	WRN3	Set up time reduction reduce material losses
4.	Waste Reduction	WRN4	Cellular manufacturing reduce material
5.	Waste Reduction	WRN5	Pre production planning reduce material
6.	Waste Reduction	WRN6	TPM reduce waste and cost
7.	Waste Reduction	WRN7	Kanban practice reduces waste and scrap
8.	Waste Reduction	WRN8	POUS reduce waste of non-value activities
9.	Waste Reduction	WRN9	Heijunka inventory reduction
10.	Waste Reduction	WRN10	Continous flow reduce scrap or backflows
11.	Waste Reduction	WRN11	Take time to prevents buildups inventory
12.	Waste Reduction	WRN12	Minimum lot size reduces WIP
13.	Waste Reduction	WRN13	Store buffer & safety stock reduce inventory

14.	Waste Reduction	WRN14	FIFO with Kanban reduce inventory
15.	Waste Reduction	WRN15	Supplier involve new product design
16.	Waste Reduction	WRN16	Supplier implement innovative material
17.	Waste Reduction	WRN17	Supplier joint approach to problem solving
18.	Waste Reduction	WRN18	Supplier collaborative in quality improve
19.	Process Center Focus	PCN1	Kaizen focus on rapid process improvement
20.	Process Center Focus	PCN2	5S help shop floor to standardized work
21.	Process Center Focus	PCN3	Set up time reduction help convert process
22.	Process Center Focus	PCN4	Cellular manufacturing efficient processing
23.	Process Center Focus	PCN5	Pre production planning reduce complexity
24.	Process Center Focus	PCN6	TPM in continuous improvement target
25.	Process Center Focus	PCN7	Kanban cards pull material
26.	Process Center Focus	PCN8	Heijunka working together balance fashion
27.	Process Center Focus	PCN9	Takt time focus in production line
28.	Process Center Focus	PCN10	Store buffer & Safety stock help production
29.	Process Center Focus	PCN11	Continuous flow synchronization
30.	Process Center Focus	PCN12	Minimum lot size to variability in system
31.	Process Center Focus	PCN13	Standard inventory reduce variation
32.	Process Center Focus	PCN14	POUS with proper 5S and transparency
33.	Process Center Focus	PCN15	Supplier improve product design
34.	High People Involvement	HPN1	Kaizen require team involvement
35.	High People Involvement	HPN2	5S gain creative input from staff
36.	High People Involvement	HPN3	SMED involve manpower
37.	High People Involvement	HPN4	Cellular manufacturing people involvement
38.	High People Involvement	HPN5	Pre production planning people involvement
39.	High People Involvement	HPN6	TPM optimized employees' performance

40.	High People Involvement	HPN7	Kanban rules to tell operators what to do
41.	High People Involvement	HPN8	Heijuka operator are important element
42.	High People Involvement	HPN9	Takt time reflect number of worker hour
43.	High People Involvement	HPN10	Continuous improvement worker practice
44.	High People Involvement	HPN11	Training to production manager pull system
45.	High People Involvement	HPN12	POUS involve employee
46.	High People Involvement	HPN13	Continuous flow worker better perform
47.	High People Involvement	HPN14	Existing supplier response environment
48.	High People Involvement	HPN15	Provide incentive to supplier to reach target
49.	High People Involvement	HPN16	Long term strategy to assess supplier operate

EFA result Lean Environment sustainability of total 49 questions. The result generated using principal component and Varimax rotation found that 23 questions had cross-loadings greater than 0.40 and 12 questions had factor loadings below 0.40 (Hair, et. al., 2010), as such the decision was made to exclude 35 questions (WRN01, WRN02, WRN03, WRN05, WRN09 WRN12, WRN13, WRN14, WRN16, WRN17, WRN18, PCN01, PCN02, PCN03, PCN04, PCN05, PCN09, PCN10, PCN11, PCN12, PCN13, PCN14, HPN01, HPN03, HPN04, HPN05, HPN06, HPN07, HPN08, HPN09, HPN10, HPN11, HPN14, HPN15, HPN16) Finally, remain 14 questions arrange to three groupings as below table.

Thus, from EFA result, the new code of lean environment sustainability practices can be seen in Table 49

Tables 49 New Code Representing Lean Environment Sustainability practices

No.	Component	Code	Indicator
1.	Waste Reduction	WRN4	Cellular manufacturing reduce material
2.	Waste Reduction	WRN6	TPM reduce waste and cost
3.	Waste Reduction	WRN7	Kanban practice reduces waste and scrap
4.	Waste Reduction	WRN8	POUS reduce waste of non-value activities

5.	Waste Reduction	WRN10	Continous flow reduce scrap or backflows
6.	Waste Reduction	WRN11	Take time to prevents buildups inventory
7.	Waste Reduction	WRN15	Supplier involve new product design
8.	Process Center Focus	PCN6	TPM in continuous improvement target
9.	Process Center Focus	PCN7	Kanban cards pull material
10.	Process Center Focus	PCN8	Heijunka working together balance fashion
11.	Process Center Focus	PCN15	Supplier improve product design
12.	High People Involvement	HPN2	5S gain creative input from staff
13.	High People Involvement	HPN12	POUS involve employee
14.	High People Involvement	HPN13	Continuous flow worker better perform

Overall, the construct validity investigated by EFA was satisfactory assured by Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett's test of sphericity values. The KMO of 0.658 demonstrated acceptable sampling sufficiency(Hoque and Awang, 2016, Awang, 2012).

The variables thus showed appropriateness for factor structure detection. The total variance explained by the three factors altogether captured 48.22 percent, the percentages of variance characterized by components 1-3 after the rotation was 19.793 percent, 14.962 percent, 13.465 percent respectively.

Tables 50 Exploratory factor analysis Rotated Component Matrix of Lean environment sustainability

	Lean Environment Sustainability		
	Waste Reduction	Process centered focus	High People's involvement & participation
WRN06	.714		
WRN11	.713		
WRN10	.675		
WRN07	.633		
WRN15	.584		

WRN04	.438		
WRN08	.428		
PCN07		.837	
PCN08		.710	
PCN15		.637	
PCN06		.599	
HPN12			.745
HPN02			.684
HPN13			.667
% of Variance	19.793	14.962	13.465
Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.658, Bartlett's Test of Sphericity = 322.783, p-value = .000			

In the next step, the variables of overall three constructs investigated the reliability Cronbach's alpha.

The component of waste reduction consist of seven variable items was perceived internal consistency at good level of Cronbach's Alpha 0.818. The component of Process centered focus consist of four variable items was perceived internal consistency at acceptable level of Cronbach's Alpha 0.727. The component of High-level People's involvement & participation consist of three variable items was perceived internal consistency at acceptable level of Cronbach's Alpha 0.700.

Reliability of component that concluded from 14 questions inform the internal consistency (See Table 51).

Tables 51 Cronbach's Alpha of Lean Environment Sustainability Component

Component	Number of items	Cronbach's Alpha	Internal Consistency
Waste Reduction	7	.818	Good
Process centered focus	4	.727	Acceptable
High People's involvement	3	.700	Acceptable

Sustainability Performance

EFA was performed with 61 indicators of sustainability performance by using the principal components method together with the Varimax rotation. Every single indicator was encoded, ranging by abbreviation below (see Table 52), and the results can be seen in Table 53 and 54.

Tables 52 Code Representing Sustainability performance

No.	Component	Code	Indicator
1.	Environment	N1	Use the land effectively
2.	Environment	N2	Reduce freshwater consumption
3.	Environment	N3	Increase amount of recycled
4.	Environment	N4	Reduce energy in production
5.	Environment	N5	Reduce energy from idle status machine
6.	Environment	N6	Use energy from renewable sources
7.	Environment	N7	Reduce material use per unit of production
8.	Environment	N8	Reduce material scrap
9.	Environment	N9	Reduce material wasted in production
10.	Environment	N10	Increase reuses or recycled material
11.	Environment	N11	Reduce packaging material used
12.	Environment	N12	Reduce material added in production
13.	Environment	N13	Reduce the amount of waste generated
14.	Environment	N14	Reduce amount of hazardous waste
15.	Environment	N15	Reduce greenhouse gas emissions
16.	Environment	N16	Reduce environmental accidents
17.	Environment	N17	Reduce EHS compliance costs
18.	Economic	E1	Increase value adding per employee

19.	Economic	E2	Improve labor vs revenue ratio
20.	Economic	E3	Good level of salary cost per hour
21.	Economic	E4	Good relative average salary level
22.	Economic	E5	Increase the number of customers
23.	Economic	E6	Reduce customer complaints
24.	Economic	E7	Increase new customer per year
25.	Economic	E8	Increase rate of new products
26.	Economic	E9	Increase R&D budget share
27.	Economic	E10	Increase overall equipment efficiency
28.	Economic	E11	Increase productivity (Production pace)
29.	Economic	E12	Increase performance rate
30.	Economic	E13	Increase delivery precision
31.	Economic	E14	Reduce production lead time
32.	Economic	E15	Reduce maintenance hour
33.	Economic	E16	Increase the number of suppliers
34.	Economic	E17	Reduce stops caused by suppliers
35.	Economic	E18	Improve percent of suppliers without EHS
36.	Economic	E19	Invest in environmental protection
37.	Economic	E20	Invest in local suppliers
38.	Economic	E21	Track costs associated with EHS
39.	Economic	E22	Stakeholder to review and participation
40.	Economic	E23	Improve products designed for disassembly
41.	Economic	E24	Increase % of products environment label
42.	Economic	E25	Track percent of products with take-back
43.	Economic	E26	Improve customer satisfaction

44.	Social	S1	General guidelines for warning and safety
45.	Social	S2	Reduce number of accidents
46.	Social	S3	Reduce absence due to injuries
47.	Social	S4	Increase training hours per employee
48.	Social	S5	Increase level of education
49.	Social	S6	Reduce rate of temporary workers
50.	Social	S7	Increase employee satisfaction rate
51.	Social	S8	Improve balance of male to female rate
52.	Social	S9	Share of employees involved in systematic
53.	Social	S10	Increase number of cross-functional team
54.	Social	S11	Reduce new employees per year
55.	Social	S12	Reduce employee turnover
56.	Social	S13	Increase support employee health care
57.	Social	S14	Allocates a budget on community
58.	Social	S15	Has a number of community partners
59.	Social	S16	Increase % of local products
60.	Social	S17	Measure ratio of wages compare
61.	Social	S18	Invests in human rights causes

EFA result sustainability performance of total 61 questions. The result generated using principal component and Varimax rotation found that 32 questions had cross-loadings greater than 0.40 and 11 questions had factor loadings below 0.40 (Hair, et. al., 2010), as such the decision was made to exclude 43 questions (E01, E02, E03, E04, E07, E11, E12, E13, E14, E19, E20, E21, E22, E23, E24, E25, E26, S03, S04, S06, S09, S10, S11, S12, S14, S15, S16, S17, S18, N01, N05, N06, N07, N08, N09, N10, N11, N12, N13, N14, N15, N16, N17) Finally, remain 18 questions arrange to three groupings as below table.

Thus, from EFA result, the new code of sustainability performance can be seen in Table 53

Tables 53 New Code Representing Sustainability performance

No.	Component	Code	Indicator
1.	Environment	N2	Reduce freshwater consumption
2.	Environment	N3	Increase amount of recycled
3.	Environment	N4	Reduce energy in production
4.	Economic	E5	Increase the number of customers
5.	Economic	E6	Reduce customer complaints
6.	Economic	E8	Increase rate of new products
7.	Economic	E9	Increase R&D budget share
8.	Economic	E10	Increase overall equipment efficiency
9.	Economic	E15	Reduce maintenance hour
10.	Economic	E16	Increase the number of suppliers
11.	Economic	E17	Reduce stops caused by suppliers
12.	Economic	E18	Improve percent of suppliers without EHS
13.	Social	S1	General guidelines for warning and safety
14.	Social	S2	Reduce number of accidents
15.	Social	S5	Increase level of education
16.	Social	S7	Increase employee satisfaction rate
17.	Social	S8	Improve balance of male to female rate
18.	Social	S13	Increase support employee health care

Overall, the construct validity investigated by EFA was satisfactory assured by Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett's test of sphericity values. The KMO of 0.722 demonstrated acceptable sampling sufficiency(Hoque and Awang, 2016, Awang, 2012). The variables thus showed appropriateness for factor structure detection. The total variance explained by the three factors altogether captured 49.42 percent, the percentages of variance characterized by components 1-3 after the rotation was 24.478 percent, 14.006 percent, 10.935 percent respectively.

Tables 54 Exploratory factor analysis Rotated Component Matrix of Sustainability Performance (n = 106)

	Component		
	Economic performance	Social performance	Environment performance
E08	.765		
E05	.761		
E16	.703		
E17	.689		
E06	.686		
E09	.671		
E10	.659		
E15	.613		
E18	.520		
S13		.774	
S05		.752	
S02		.667	
S07		.599	
S01		.552	
N03			.808
N04			.641
N02			.635
S08			.459
% of Variance	24.478	14.006	10.935
Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.722, Bartlett's Test of Sphericity = 658.707, p-value = .000			

In the next step, the variables of overall three constructs investigated the reliability Cronbach's alpha.

The component of environment performance consist of nine variable items was perceived internal consistency at good level of Cronbach's Alpha 0.889. The component of social performance consist of five variable items was perceived internal consistency at acceptable level of Cronbach's Alpha 0.781. The component of environment performance consist of four variable items was perceived internal consistency at acceptable level of Cronbach's Alpha 0.748.

Reliability of component that concluded from 18 questions inform the internal consistency (See Table 55).

Tables 55 Cronbach's Alpha of Sustainability Performance Component

Component	Number of items	Cronbach's Alpha	Internal Consistency
Economic performance	9	.889	Good
Social performance	5	.781	Acceptable
Environment performance	4	.748	Acceptable

4.5.2 Measurement Model of Lean Sustainability - Confirmatory factor analysis (CFA)

This section is considered as the first procedure of SEM following the prevailing two-step modelling approach advocated. In the next step, CFA was performed chosen three hundred (300) samples from this study which was an appropriate technique utilized for this study since the proposed hypothesized model was developed from the theory and past empirical studies. At his stage, a series of CFA was performed to examine each measurement model of the five focal constructs aiming to 1) test the good fit of each measurement model as well as an overall measurement model to evaluate whether the sample data fit the proposed measurement model and 2) determine the construct validity convergent and discriminant validity (Hair et al., 2014). AMOS v.22 was applied for CFA application.

Initially, each construct was evaluated for the measurement model fit against the acceptable thresholds of the six indices; chi-square/df (χ^2/Df) ≤ 3.00, comparative fit index (CFI) ≥ 0.90, root mean square error of approximation (RMSEA) ≤ 0.07, standardized root mean square residual (RMR) ≤ 0.08, (Hair et al., 2014); Goodness of fit index (GFI) ≥ 0.90 , and Normed Fit Index (NFI) ≥ 0.90 (Schumacker and Lomax, 2016). If any measurement model did not fit the data well, a model modification would be considered by eliminating the indicators with factor loadings below 0.5 (Hair et al., 2010) or with high correlation measurement errors through the review of modification indices (MI) to improve or achieve the model fit.

Reliability and convergent validity were substantially examined. Cronbach's alpha of greater than0.70 was used to describe the acceptable internal consistency of each latent variable. Convergent validity is one of the methods used to assess the construct validity and refers to "the Degree to which to measures of the same concept are correlated" (Schumacker and Lomax, 2016). Composite reliability (CR) and average variance extracted (AVE) were used to assess the convergent validity with the suggested cut-off values of 0.7 and 0.5 or above(Hair et al., 2014), respectively. After all the measurement models achieved the model fit. Reliability, and convergent validity, all latent variables along with their final measurement scales were loaded to test the correlation among the four constructs of the study as well as for discriminant validity test before progressing to the second step of SEM analysis, structural modeling, and the research hypotheses testing.

In the current study, second-order CFA was applied to examine the four constructs, lean social sustainability (LSS), lean economic sustainability (LECS), lean environment sustainability (LENS), and sustainability performance (SP), which were conceptually and empirically specified as a higher-order factor. Thus, the results of CFA applications were presented throughout this section.

a. Assessment of Measurement Model Fit for Lean Social Sustainability - Confirmatory factor analysis (CFA)

Three components of lean social sustainability were investigated for the model fit by the CFA process. The abbreviation of the latent construct and indicators were specified lean social sustainability (LSS).

Tables 56 Sub-category of lean social sustainability

Construct	Observed Variables	Abbreviation
Lean Social Sustainability		LSS
	Work Force	WFS
	Information Transparency	ITS
	Community Contribution	CCS

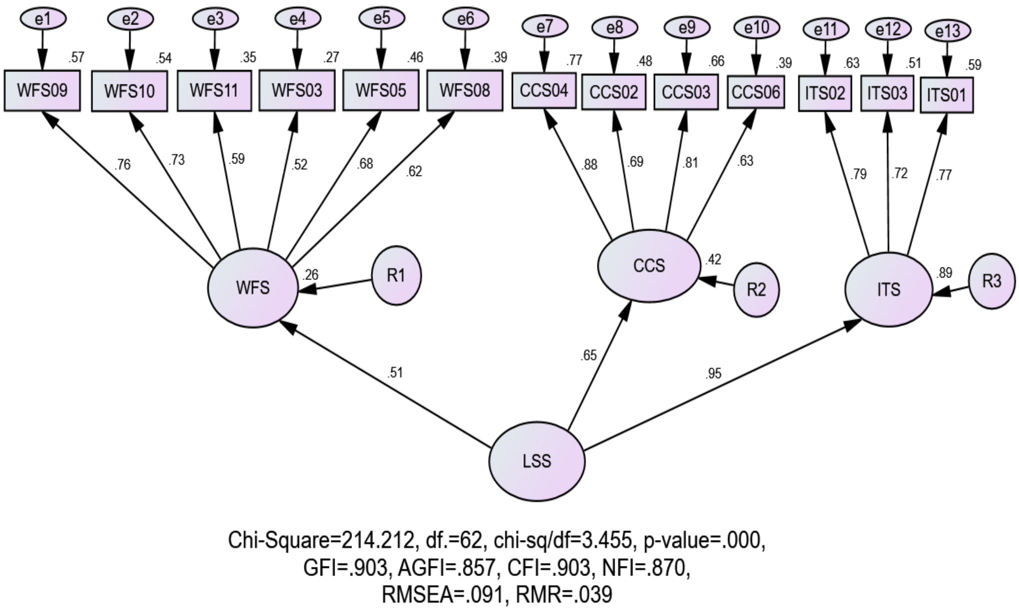
In the process of second-order CFA was conducted to evaluate LSS, a higher-order factor, consisting of three first-order factors, work force (WFS), Information Transparency (ITS), and Community Contribution (CCS). The initial measurement model of LSS with a total of 13 indicators result from overall, the construct validity investigated by EFA was satisfactory (see Table 41 and 42 for the full details) was preliminarily evaluate and produced the following results CFA demonstrated model fit indices χ^2/Df=3.455, GFI=0.903, CFI=0.903, NFI=0.870, RMSEA=0.091, RMR=0.039. The tasted model for lean social sustainability is shown in figure 16. The fit indices revealed that the initial estimation of CFA for perceived LSS with thirteen observed variables did not provide an appropriate fit to the sample data. There was a need for further modification that could affect χ^2/Df less than 3 and NFI higher than 0.90, RMSEA less than 0.07. After modification the results of CFA demonstrated acceptable model fit indices χ^2/Df=1.164, GFI=0.971, CFI=0.995, NFI=0.965, RMSEA=0.023, RMR=0.025. ✓There was no need for further modification.

Tables 57 CFA of Lean Social Sustainability

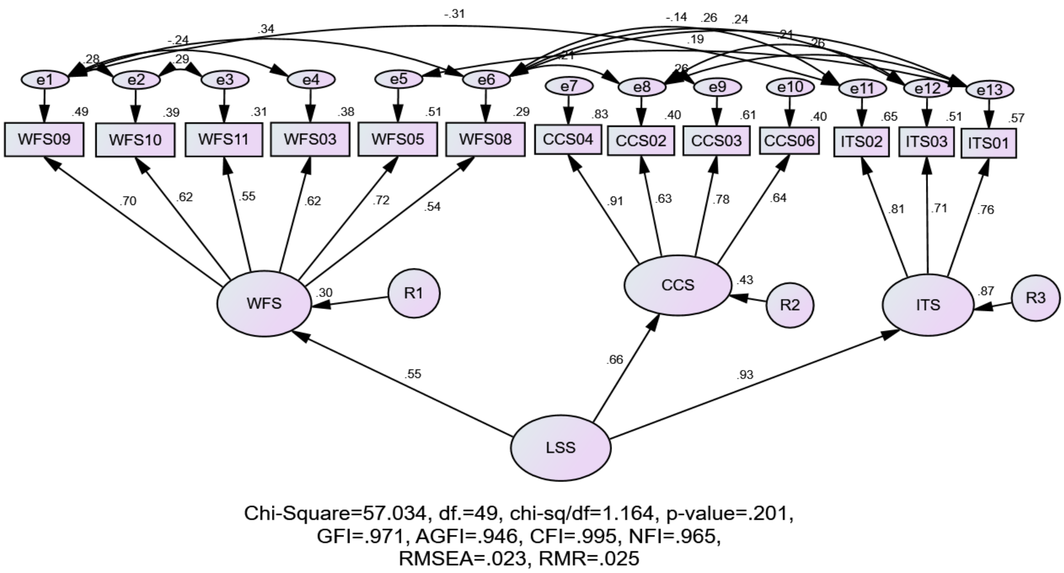
	χ^2	Df	p-value	χ^2/Df	GFI	CFI	NFI	RMSEA	RMR

Criteria	-	-	-	≤ 3.00	≥ 0.90	≥ 0.90	≥ 0.90	≤ 0.07	≤ 0.08
Initial model	214.212	62	.000	3.455	.903	.903	.870	.091	.039
Final model	57.034	49	.201	1.164	.971	.995	.965	.023	.025

Note: χ^2 = Chi-squares, Df = Degree of freedom, GFI = Goodness of fit index, CFI = comparative fit index, NFI = Normed Fit Index, RMSEA = root mean square error of approximation, RMR = root mean square residual.



Figures 16 Initial model of Lean Social Sustainability



Figures 17 Final model of Lean Social Sustainability

b. Reliability and Convergent Validity of Lean Social Sustainability (LSS)

Table 58 presents the standardized factor loading β and t-value (t) of all 13 indicators loaded on their corresponding latent variables as well as the results of construct reliability of the modified lean social sustainability (LSS) measurement model. The magnitudes of the β weight of 13 indicators ranged between 0.61-0.90 exceeding the suggested level (>0.50). Out of 13 indicators, 6 indicators were above 0.70. In terms of the first order latent variables loaded on LSS construct, community contribution obtained the highest loading (β=0.934) indicating that community contribution was the most vital indicator of LSS construct followed by information transparency (β=0.656), and work force (β=0.551), and all were statistically significant ($p < 0.001$).

The overall Cronbach's alpha coefficient of the modified LSS scales was 0.858 in which the alpha by each first-order construct value 0.813 (work force), 0.836 (community contribution); and 0.801 (information transparency) exceeding the suggested level (>0.70). The composite reliability or construct reliability (CR) by each first-order construct were 0.794 (work force),0.832 (community contribution), and 0.805 (information transparency) with overall CR of 0.767 for LSS construct exceeding a cut-off value of 0.70. Further, the average variance extracted (AVE) of all first-order latent variables (WFS=0.394, CCS=0.559, ITS=0.580) and second order LSS construct (0.535) were greater than the acceptable thresholds of 0.50.

The above findings of model fit indices, significant factor loadings, reliability coefficient, AVEs, and CR, confirmed the convergent validity for the LSS scales (Schumacker and Lomax, 2016). Thus, the 13 measurement items loaded on their respective latent factors (6 items on WFS, 4 items on CCS, and 3 items on ITS) for the final LSS model were reliable and adequate for further analysis.

Tables 58 Result of Second order CFA for Modified LSS Model

Construct/Indicators	β	*t*-value	R^2	CR	AVE
Lean social sustainability *(α =.858)*	**-**	**-**	**-**	**.767**	**.535**
Work force *(α =.813)*	**0.551**	**-**	**0.304**	**.794**	**.394**
WFS09	0.696	-	0.485		
WFS10	0.621	9.843***	0.386		
WFS11	0.553	7.647***	0.306		
WFS03	0.619	7.836***	0.383		
WFS05	0.717	8.997***	0.513		
WFS08	0.541	9.388***	0.293		
Community contribution *(α =.836)*	**0.934**	**5.002*** **	**0.872**	***.832***	**.559**
CCS04	0.909	-	0.827		
CCS02	0.631	11.103***	0.398		
CCS03	0.781	14.067***	0.609		
CCS06	0.635	11.394***	0.404		
Information Transparency *(α = .801)*	**0.656**	**6.100*** **	***0.430***	***.805***	**.580**

ITS02		0.809	-	0.655		
ITS03		0.714	11.837***	0.509		
ITS01		0.758	12.441***	0.575		

Note: all indicators are significant at $p < 0.001$, the path of WFS09, CCS04, and ITS02 were fixed to 1 (not estimated). α = Cronbach's alpha coefficient, CR = construct reliability or composite reliability, AVE = average variance extracted.

Table 59 presents Discriminant validity and correlation matrix among four constructs

The degree to which two conceptually similar concepts are different is referred to as discriminant validity" (Hair, Black et al. 2014). Specifically, the four constructs of the study should not be highly intercorrelated, correlation coefficient below 0.90, to confirm that each construct explains its indicators instead of other constructs in the model (Kline 2011). This study utilized the criterion set by Formell and Larcker (1981) to test the discriminant validity of the three constructs. The relationship of each pair or the estimated correlation coefficients of latent constructs was compared with the square root of AVE (average variance extracted) of latent constructs. Thus, the estimated correlations among the three constructs should be lower than the square root of AVE to establish the discriminant (Hair, Ringle et al. 2011, Hair Jr, Hult et al. 2016).

Tables 59 Discriminant Validity Result for LSS Model

Lean Social Sustainability	Work force	Community contribution	Information Transparency
Work force	**0.628**		
Community contribution	0.515***	**0.748**	
Information Transparency	0.362***	0.613***	**0.762**

Note: n=300, LSS: Lean Social Sustainability, WFS: Work Force, CCS: Community Contribution Sustainability, ITS: Information Transparency, AVE: Average variance extracted, Diagonal figures in bold represent the square root of AVE of the latent variables.

As reported in Figure 17 and Table 59 the relationship between three constructs existed with the positive correlation coefficients from 0.362 (WFS and ITS) to 0.613 (CCS and ITS) indicating low to moderate relationship among the constructs. The square roots of

AVE (as-presented as the diagonal figures in bold in Table 59 of work force practices WFS (0.628), community contribution CCS (0.748), and information transparency ITS (0.762) were greater than the estimated correlation coefficients (off-diagonal figures) relationship among the constructs. Overall, the discriminant validity for this measurement model and the three constructs was fully supported which had strong relationship between constructs.

c. Assessment of Measurement Model Fit for Lean Economic Sustainability - Confirmatory factor analysis (CFA)

Two components of lean economic sustainability were investigated for the model fit by the CFA process. The abbreviation of the latent construct and indicators were specified lean economic sustainability (LECS).

Tables 60 Sub-category of lean economic sustainability

Construct	Observed Variables	Abbreviation
Lean Economic Sustainability		LECS
	Physical Productivity	PPE
	Product Quality	PQE

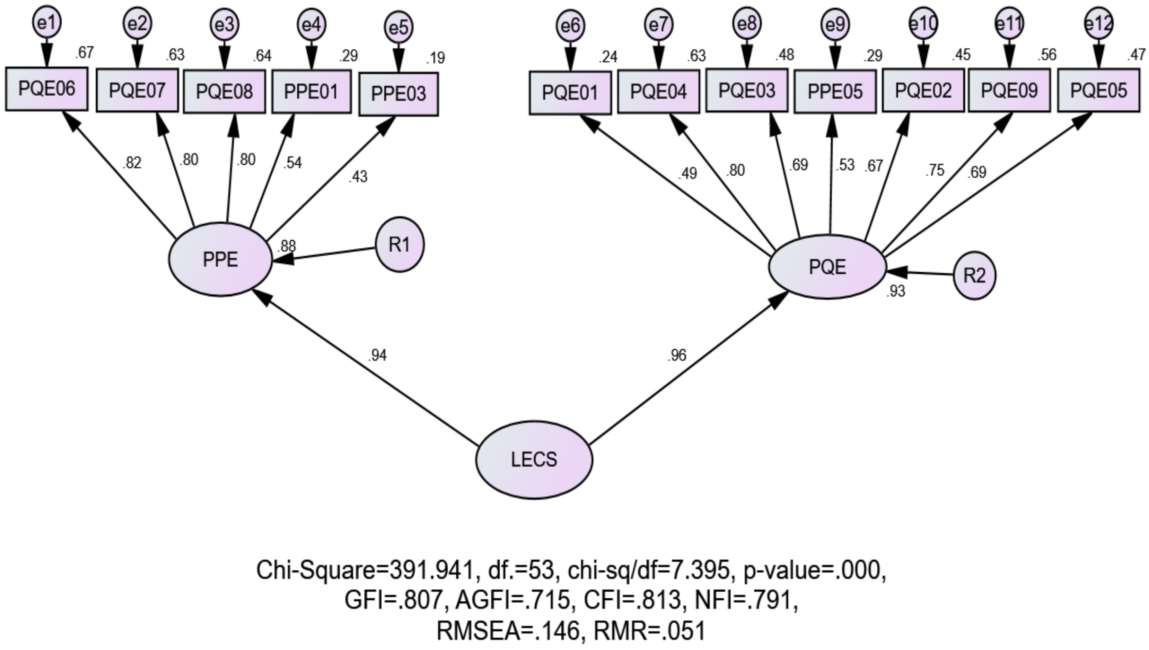
In the process of second-order CFA was conducted to evaluate LECS, a higher-order factor, consisting of two first-order factors, physical productivity (PPE), and product quality (PQE), The initial measurement model of LECS with a total of 12 indicators result from overall, the construct validity investigated by EFA was satisfactory (see Table 61 and 62 for the full details) was preliminarily evaluate and produced the following results CFA demonstrated model fit indices χ^2/Df=7.395, GFI=0.807, CFI=0.813, NFI=0.791, RMSEA=0.146, RMR=0.051. The tasted model for lean economic sustainability is shown in figure 18. The fit indices revealed that the initial estimation of CFA for perceived LECS with twelve observed variables did not provide an appropriate fit to the sample data. There was a need for further modification that could affect χ^2/Df less than 3 , GFI , CFI , and NFI higher than 0.90.

Tables 61 CFA of Lean Economic Sustainability

	χ^2	Df	p-value	χ^2/Df	GFI	CFI	NFI	RMSEA	RMR
Criteria	-	-	-	≤ 3.00	≥ 0.90	≥ 0.90	≥ 0.90	≤ 0.07	≤ 0.08
Initial model	391.941	53	.000	7.395	.807	.813	.791	.146	.051
Final model	41.300	34	.182	1.215	.978	.996	.978	.027	.020

Note: χ^2 = Chi-squares, Df = Degree of freedom, GFI = Goodness of fit index, CFI = comparative fit index, NFI = Normed Fit Index, RMSEA = root mean square error of approximation, RMR = root mean square residual

After modification the results of CFA demonstrated acceptable model fit indices χ^2/Df=1.215, GFI=0.978, CFI=0.996, NFI=0.978, RMSEA=0.027, RMR=0.020. There was no need for further modification.



Figures 18 Initial model of Lean Economic Sustainability

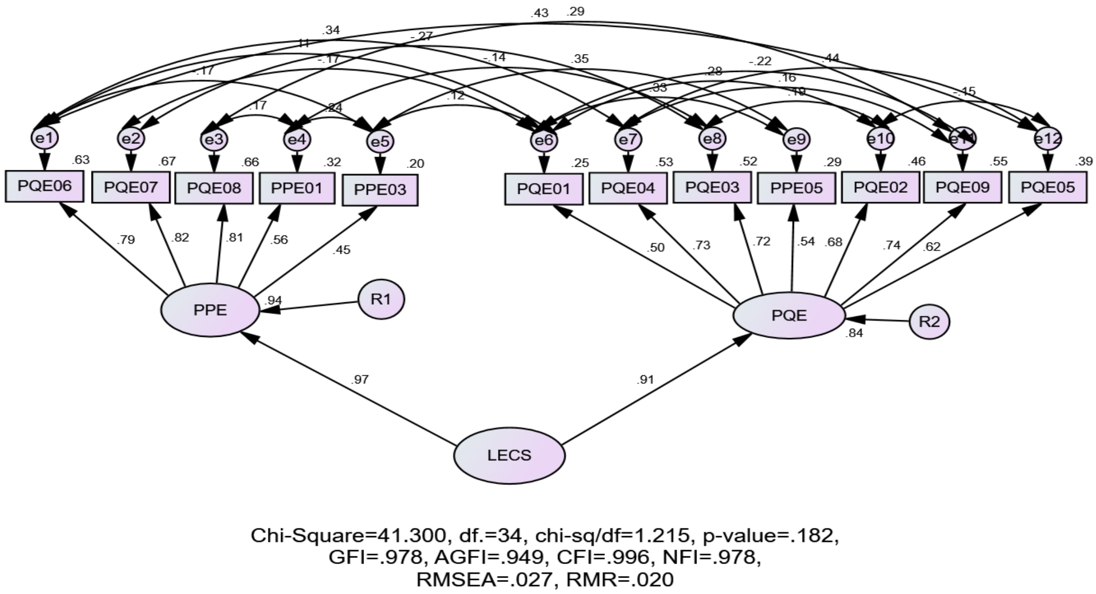


Figure 1 Final model of Lean Economic Sustainability

d. Reliability and Convergent Validity of Lean Economic Sustainability (LECS)

Table 62 presents the standardized factor loading β and t-value (t) of all 12 indicators loaded on their corresponding latent variables as well as the results of construct reliability of the modified LECS measurement model. The magnitudes of the β weight of 12 indicators ranged between 0.50-0.82 exceeding the suggested level (>0.50). Out of 12 indicators, 6 indicators were above 0.70. In terms of the first order latent variables loaded on LECS construct, physical productivity obtained the highest loading (β=0.969) indicating that physical productivity was the most vital indicator of LECS construct followed by product quality (β=0.914), and all were statistically significant ($p < 0.001$).

The overall Cronbach's alpha coefficient of the modified LECS scales was 0.901 in which the alpha by each first-order construct value 0.833 (physical productivity), and 0.846 (product quality exceeding the suggested level (>0.70). The composite reliability or construct reliability (CR) by each first-order construct were 0.825 (physical productivity), and 0.836 (product quality), with overall CR of 0.940 for LECS construct exceeding a cut-off value of 0.70. Further, the average variance extracted (AVE) of all first-order latent variables (PPE=0.497, PQE=0.426) and second order LECS construct (0.887) were greater than the acceptable thresholds of 0.50.

The above findings of model fit indices, significant factor loadings, reliability coefficient, AVEs, and CR, confirmed the convergent validity for the LECS scales (Schumacker and Lomax, 2016). Thus, the 12 measurement items loaded on their respective latent factors (5 items on PPE, and 7 items on PQE) for the final LECS model were reliable and adequate for further analysis.

Tables 62 Result of Second order CFA for Modified LSS Model

Construct/Indicators		β	*t*-value	R^2	CR	AVE
Lean Economic Sustainability *(α =.901)*		-	-	-	**.940**	**.887**
Physical productivity *(α =.833)*		0.969		0.939	**.825**	**.497**
PQE06		0.793		0.629		
PQE07		0.821	15.038***	0.675		
PQE08		0.811	14.49***	0.658		
PPE01		0.563	9.469***	0.317		
PPE03		0.500	7.222***	0.250		
Product quality *(α =.846)*		0.914	6.462***	0.836	**.836**	**.426**
PQE01		0.502		0.252		
PQE04		0.729	7.832***	0.531		
PQE03		0.718	7.680***	0.516		
PQE02		0.677	8.629***	0.287		
PPE05		0.535	8.150***	0.458		

PQE09		0.741	7.361***	0.549		
PQE05		0.625	7.273***	0.39		

Note: all indicators are significant at $p < 0.001$, the path of PQE06, and PQE01 were fixed to 1 (not estimated). α = Cronbach's alpha coefficient, CR = construct reliability or composite reliability, AVE = average variance extracted.

Tables 63 Discriminant Validity Result for LECS Model

Lean Economic Sustainability	Physical Productivity	Product Quality
Physical productivity	**0.705**	
Product quality	0.886***	**0.653**

Note: n=300, LECS: Lean Economic Sustainability, PPE: Physical Productivity, PQE: Product Quality, AVE: Average variance extracted, Diagonal figures in bold represent the square root of AVE of the latent variables.

As reported in Figure 19 and Table 63, the relationship between two constructs existed with the positive correlation coefficients was 0.886 (PPE and PQE) indicating high relationship between the constructs. The square roots of AVE (as-presented as the diagonal figures in bold in Table 63 of physical productivity (PPE) (0.705), and product quality (PQE) (0.653 were lower than the estimated correlation coefficients (off-diagonal figures) relationship among the constructs. Overall, the discriminant validity for this measurement model and the two constructs was not fully supported**.**

e. Assessment of Measurement Model Fit for Lean Environment Sustainability - Confirmatory factor analysis (CFA)

Three components of lean environment sustainability were investigated for the model fit by the CFA process. The abbreviation of the latent construct and indicators were specified lean environment sustainability (LENS).

Tables 64 Sub-category of lean environment sustainability

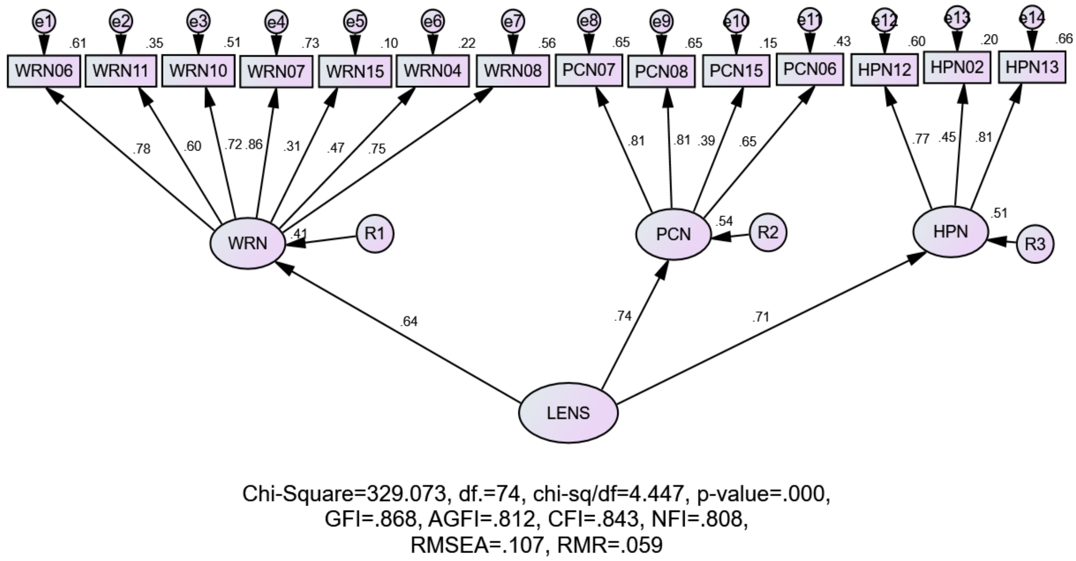
Construct	Observed Variables	Abbreviation
Lean Environment Sustainability		LENS
	Waste Reduction	WRN
	Process centered focus	PCN
	High people's involvement	HPN

In the process of second-order CFA was conducted to evaluate LENS, a higher-order factor, consisting of three first-order factors, waste reduction (WRN), process centered focus (PCN), and high people's involvement & participation (HPN). The initial measurement model of LENS with a total of 14 indicators result from overall, the construct validity investigated by EFA was satisfactory (see Table 46 and 47 for the full details) was preliminarily evaluate and produced the following results CFA demonstrated model fit indices χ^2/Df=4.447, GFI=0.868, CFI=0.843, NFI=0.808, RMSEA=0.107, RMR=0.059. The tasted model for lean environment sustainability is shown in figure 20. The fit indices revealed that the initial estimation of CFA for perceived LENS with fourteen observed variables did not provide an appropriate fit to the sample data. There was a need for further modification that could affect χ^2/Df less than 3 and GFI,CFI, and NFI higher than 0.90.

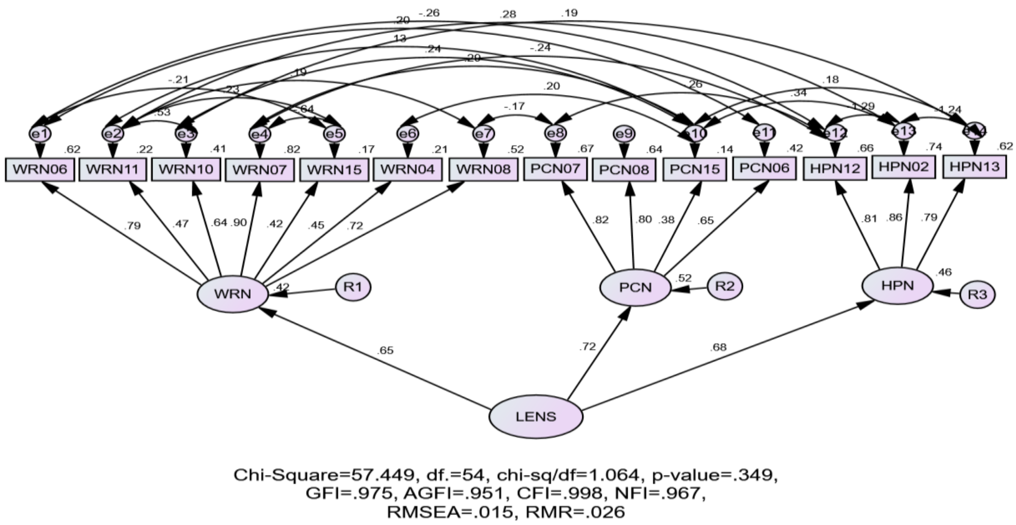
Tables 65 CFA of Lean Environment Sustainability

	χ^2	Df	p-value	χ^2/Df	GFI	CFI	NFI	RMSEA	RMR
Criteria	-	-	-	≤ 3.00	≥ 0.90	≥ 0.90	≥ 0.90	≤ 0.07	≤ 0.08
Initial model	329.073	74	.000	4.447	.868	.843	.808	.107	.059
1st modification	57.449	54	.349	1.064	.975	.998	.967	.015	.026
Final model	27.092	24	.300	1.129	.982	.997	.978	.021	.022

After first modification the results of CFA demonstrated acceptable model fit indices χ^2/Df=1.064, GFI=0.975, CFI=0.998, NFI=0.967, RMSEA=0.015, RMR=0.026. However, the result found the β weight of 14 indicators, there were 4 indicators β weight below 0.50 as shown in Figure 21. Therefore, there was necessary for further modification (See figure 22). After final modification the results of CFA demonstrated acceptable model fit indices χ^2/Df=1.129, GFI=0.982, CFI=0.997, NFI=0.978, RMSEA=0.021, RMR=0.022. There was no need for further modification.



Figures 19 Initial model of Lean Environment Sustainability



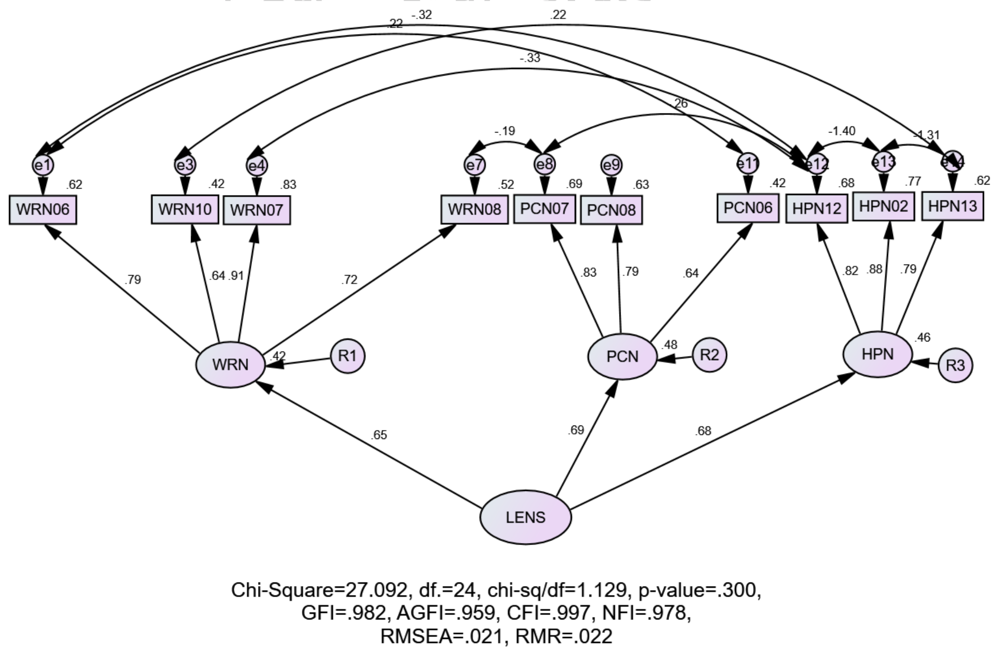
Figures 20 1st modification model of Lean Environment Sustainability

f. Reliability and Convergent Validity of Lean Environment Sustainability (LENS)

Table 66 presents the standardized factor loading β and t-value (t) of all 14 indicators loaded on their corresponding latent variables as well as the results of construct reliability of the modified LENS measurement model. The magnitudes of the β weight of 14 indicators, there were 4 indicators β weight below 0.50 from WRN 04 (β=0.45), WRN11 (β=0.47), WRN15 (β=0.42), PCN15 (β=0.36). The decision to remove these 4 indicators and remain 10 indicators ranged between 0.64-0.91 exceeding the suggested level (>0.50). Out of 10 indicators, 8 indicators were above 0.70. In terms of the first order latent variables loaded on LENS construct, process center focus obtained the highest loading (β=0.691) indicating that process center focus was the most vital indicator of LENS construct followed by high people's involvement & participation (β=0.682), and waste reduction (β=0.650), and all were statistically significant ($p < 0.001$).

The overall Cronbach's alpha coefficient of the modified LENS scales was 0.846 in which the alpha by each first-order construct value 0.836 (waste reduction), 0.741 (process center focus); and 0.700 (High people's involvement & participation) exceeding the suggested level (>0.70). The composite reliability or construct reliability (CR) by each first-order construct were 0.854 (waste reduction),0.802 (process center focus), and 0.870 (high people's involvement and participation) with overall CR of 0.715 for LENS construct exceeding a cut-off value of 0.70. Further, the average variance extracted (AVE) of all first-order latent variables (WRN=0.598, PCN=0.578, HPN=0.690) and second order LENS construct (0.500) were meet the acceptable thresholds of 0.50.

The above findings of model fit indices, significant factor loadings, reliability coefficient, AVEs, and CR, confirmed the convergent validity for the LSS scales (Schumacker and Lomax, 2016). Thus, the 10 measurement items loaded on their respective latent factors (4 items on WRN, 3 items on PCN, and 3 items on HRN) for the final LENS model were reliable and adequate for further analysis.



Figures 21 Final model of Lean Environment Sustainability

Tables 66 Result of Second order CFA for Modified LENS Model

Construct/Indicators	β	*t*-value	R^2	CR	AVE
Lean Environment Sustainability *(α.846)*				**.715**	**.500**

Waste Reduction *(α =.836)*	.650	-	.423	**.854**	**.598**
WRN06	.789	-	.622		
WRN10	.645	11.481	.416		
WRN07	.913	16.279	.833		
WRN08	.721	13.048	.520		
Process centered focus *(α =.741)*	.691	6.504	.478	**.802**	**.578**
PCN07	.830	-	.689		
PCN08	.794	12.476	.631		
PCN06	.644	10.692	.415		
High People's involvement & participation*(α=.687)*	.682	5.168	.465	***.870***	**.690**
HPN12	.822	-	.676		
HPN02	.878	6.292	.771		
HPN13	.790	7.884	.625		

Note: all indicators are significant at $p < 0.001$, the path of WRN06, PCN07, and HPN12 were fixed to 1 (not estimated). α = Cronbach's alpha coefficient, CR = construct reliability or composite reliability, AVE = average variance extracted.

Tables 67 Discriminant Validity Result for LENS Model

Lean Environment Sustainability	Waste Reduction	Process Center Focus	High People's involvement and participation
Waste Reduction	**0.773**		
Process Center Focus	0.450***	**0.760**	
High People's involvement and participation	0.443***	.471***	**0.831**

Note: n=300, LENS: Lean Environment Sustainability, WRN: Waste Reduction, PCN: Process Center Focus, HPN: High people's involvement and participation, AVE: Average variance extracted, Diagonal figures in bold represent the square root of AVE of the latent variables.

As reported in Figure 22 and Table 67, the relationship between three constructs existed with the positive correlation coefficients from 0.443 (WRN and HPN) to 0.471 (PCN and HPN) indicating low relationship among the constructs. The square roots of AVE (as-presented as the diagonal figures in bold in Table 67 of waste reduction WRN (0.773), process center focus PCN (0.760), and high people involvement and participation (0.831) were greater than the estimated correlation coefficients (off-diagonal figures) relationship among the constructs. Overall, the discriminant validity for this measurement model and the three constructs was fully supported which had strong relationship between constructs.

Thus, from CFA result, the new code of lean environment sustainability practices can be seen in Table 68

Tables 68 New Code Representing Lean Environment Sustainability practices

No.	Component	Code	Indicator
1.	Waste Reduction	WRN6	TPM reduce waste and cost
2.	Waste Reduction	WRN7	Kanban practice reduces waste
3.	Waste Reduction	WRN8	POUS reduce waste of non-value
4.	Waste Reduction	WRN10	Continous flow reduce scrap
5.	Process Center Focus	PCN6	TPM in continue improve target
6.	Process Center Focus	PCN7	Kanban cards pull material
7.	Process Center Focus	PCN8	Heijunka working together
8.	High People Involvement	HPN2	5S gain creative input from staff
9.	High People Involvement	HPN12	POUS involve employee
10.	High People Involvement	HPN13	Continuous flow worker perform

g. Assessment of Measurement Model Fit for Sustainability Performance - Confirmatory factor analysis (CFA)

Three components of sustainability performance were investigated for the model fit by the CFA process. The abbreviation of the latent construct and indicators were specified sustainability performance (SP).

Tables 69 Sub-category of sustainability performance

Construct	Observed Variables	Abbreviation
Sustainability Performance		SP
	Social Performance	SPS
	Economic Performance	SPEC
	Environment Performance	SPEN

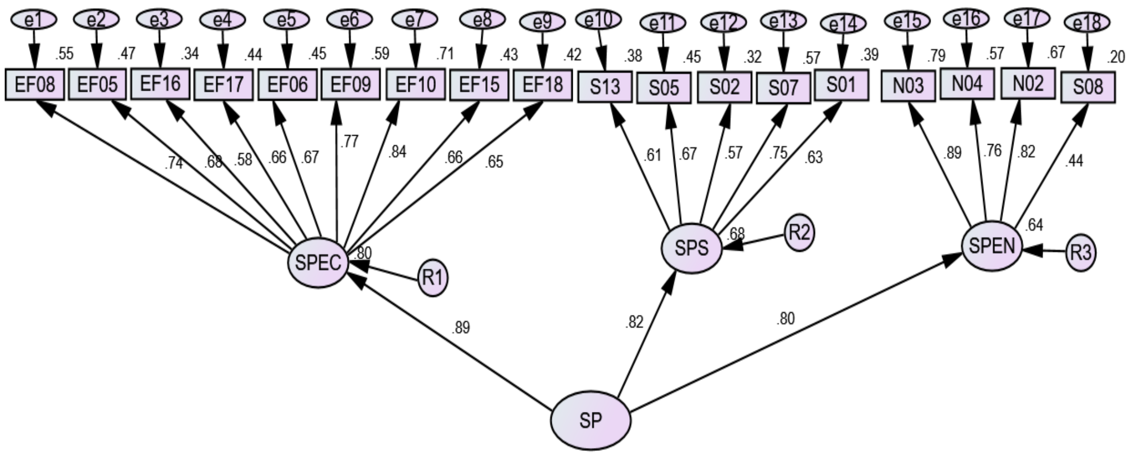
In the process of second-order CFA was conducted to evaluate SP, a higher-order factor, consisting of three first-order factors, social performance (SPS), economic performance (SPEC), and environment performance (SPEN). The initial measurement model of SP with a total of 18 indicators result from overall, the construct validity investigated by EFA was satisfactory (see Table 49 and 50

for the full details) was preliminarily evaluate and produced the following results CFA demonstrated model fit indices χ^2/Df=5.618, GFI=0.783, CFI=0.792, NFI=0.760, RMSEA=0.124, RMR=0.064. The tasted model for sustainability performance is shown in figure 23. The fit indices revealed that the initial estimation of CFA for perceived SP with eighteen observed variables did not provide an appropriate fit to the sample data. There was a need for further modification that could affect χ^2/Df less than 3 and GFI, CFI, and NFI higher than 0.90, RMSEA less than 0.07.

Tables 70 CFA of Sustainability Performance

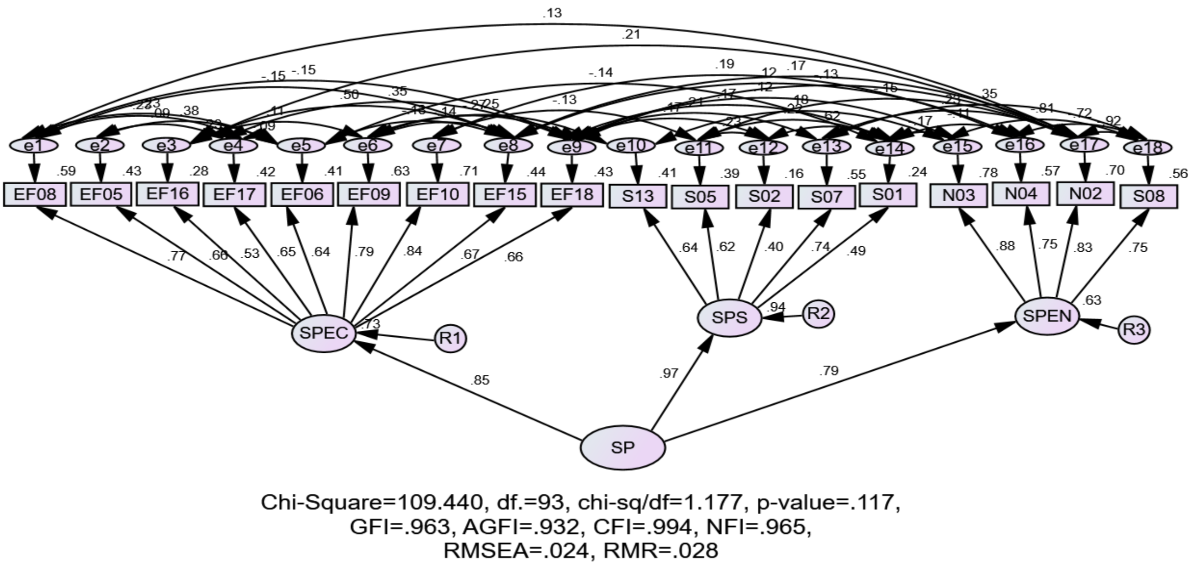
	χ^2	Df	p-value	χ^2/Df	GFI	CFI	NFI	RMSEA	RMR
Criteria	-	-	-	≤ 3.00	≥ 0.90	≥ 0.90	≥ 0.90	≤ 0.07	≤ 0.08
Initial model	742.555	132	.000	5.618	.783	.792	.760	.124	.064
1st modification	109.440	93	.117	1.177	.963	.994	.965	.024	.028
Final model	81.754	77	.334	1.062	.968	.998	.970	.014	.024

After modification the results of CFA demonstrated acceptable model fit indices χ^2/Df=1.177, GFI=0.963, CFI=0.994, NFI=0.965, RMSEA=0.024, RMR=0.028. However, the result found the β weight of 18 indicators, there were 2 indicators β weight below 0.50 as shown in Figure 24. Therefore, there was necessary for further modification (See figure 25). After final modification the results of CFA demonstrated acceptable model fit indices χ^2/Df=1.062, GFI=0.968, CFI=0.998, NFI=0.970, RMSEA=0.014, RMR=0.024. There was no need for further modification.



Chi-Square=741.555, df.=132, chi-sq/df=5.618, p-value=.000,
GFI=.783, AGFI=.719, CFI=.792, NFI=.760,
RMSEA=.124, RMR=.064

Figures 22 Initial model of Sustainability Performance



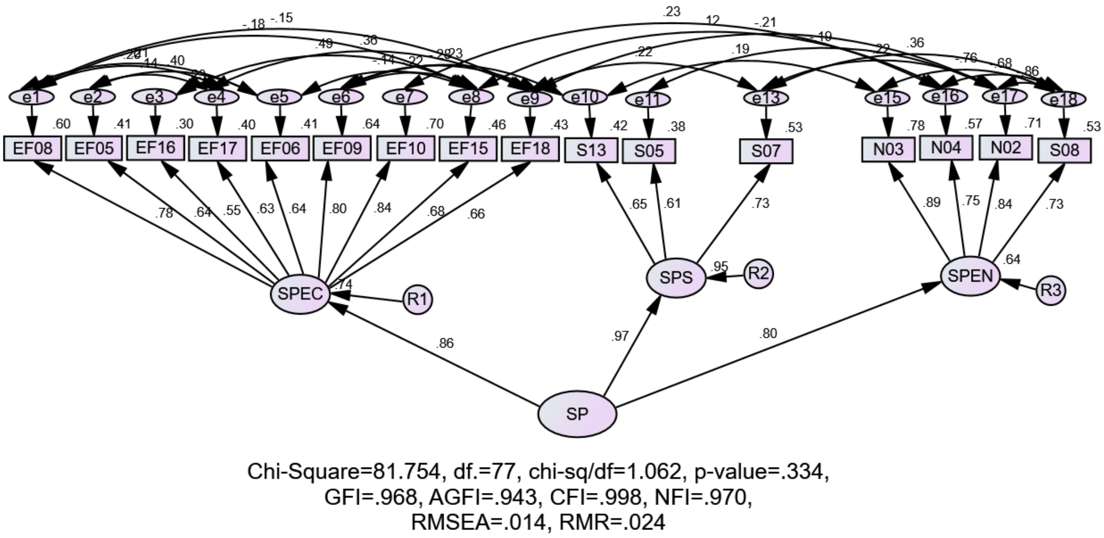
Figures 23 1st modification model of Sustainability Performance

h. Reliability and Convergent Validity of Sustainability Performance (SP)

Table 71 presents the standardized factor loading β and t-value (t) of all 18 indicators there were 2 indicators β weight below 0.50 from S02 (β=0.40) , S01(β=0.49), The decision to remove these 2 indicators and remain 16 indicators ranged between 0.61-0.88 exceeding the suggested level (>0.50). Out of 16 indicators, 8 indicators were above 0.70. loaded on their corresponding latent variables as well as the results of construct reliability of the modified SP measurement model. The magnitudes of the β weight of 18 indicators ranged between 0.53-0.88 exceeding the suggested level (>0.50). Out of 18 indicators, 8 indicators were above 0.70. In terms of the first order latent variables loaded on SP construct, social performance obtained the highest loading (β=0.974) indicating that social performance was the most vital indicator of SP construct followed by economic performance (β=0.859), and environment (β=0.798), and all were statistically significant (p < 0.001).

The overall Cronbach's alpha coefficient of the modified SP scales was 0.921 in which the alpha by each first-order construct value 0.895 (economic performance), 0.788 (social); and 0.796 (environment performance) exceeding the suggested level (>0.70). The composite reliability or construct reliability (CR) by each first-order construct were 0.893 (economic performance),0.701 (social performance), and 0.880 (environment performance) with overall CR of 0.911 for SP construct exceeding a cut-off value of 0.70. Further, the average variance extracted (AVE) of all first-order latent variables (SPEC=0.485, SPS=0.441, SPEN=0.648) and second order SP construct (0.774) were greater than the acceptable thresholds of 0.50.

The above findings of model fit indices, significant factor loadings, reliability coefficient, AVEs, and CR, confirmed the convergent validity for the SP scales (Schumacker and Lomax, 2016). Thus, the 16 measurement items loaded on their respective latent factors (9 items on SPEC, 3 items on SPS, and 4 items on SPEN) for the final SP model were reliable and adequate for further analysis.



Figures 24 Final model of Sustainability Performance

Tables 71 Result of Second order CFA for Modified SP Model

Construct/Indicators	β	*t*-value	R^2	CR	AVE

Sustainability Performance *(α =.921)*					**.911**	**.774**
Economic performance *(α =.895)*		0.859	-	0.737	**.893**	**.485**
EF08		0.776	-	0.603		
EF05		0.642	11.285	0.412		
EF16		0.550	9.484	0.302		
EF17		0.635	10.215	0.403		
EF06		0.638	12.377	0.407		
EF09		0.801	14.350	0.641		
EF10		0.837	15.271	0.700		
EF15		0.681	11.047	0.463		
EF18		0.656	10.710	0.430		
Social performanace *(α =.788)*		0.974	9.506	0.948	**.701**	**.441**
S13		0.645	-	0.416		
S05		0.614	8.792	0.376		
S07		0.727	9.999	0.528		
Environment performance *(α =.796)*		0.798	10.546	0.637	***.880***	**.648**
N03		0.886	-	0.784		
N04		0.753	15.403	0.567		
N02		0.844	17.421	0.712		
S08		0.727	8.676	0.528		

Note: all indicators are significant at $p < 0.001$, the path of SPEC, EF08, and S13, were fixed to 1 (not estimated). α = Cronbach's alpha coefficient, CR = construct reliability or composite reliability, AVE = average variance extracted.

Tables 72 Discriminant Validity Result for SP Model

Sustainability Performance	Economic Sustainability	Social Sustainability	Environment Sustainability
Economic Sustainability	**0.696**		
Social Sustainability	0.836***	**0.664**	
Environment Sustainability	0.685***	0.777***	**0.805**

Note: n=300, SP: Sustainability Performance, SPEC: Economic Sustainability, SPS: Social Sustainability, SPEN: Environment Sustainability, AVE: Average variance extracted, Diagonal figures in bold represent the square root of AVE of the latent variables.

As reported in Figure 25 and Table 72, the relationship between three constructs existed with the positive correlation coefficients from 0.685 (SPEC and SPEN) to 0.777 (SPS and SPEN) indicating moderate to high relationship among the constructs. The square roots of AVE (as-presented as the diagonal figures in bold in Table 72 of economic sustainability SPEC (0.696), social sustainability SPS (0.664), were lower than the estimated correlation coefficients (off-diagonal figures) relationship among the constructs. Environment sustainability SPEN (0.805) was higher than the estimated correlation coefficients (off-diagonal figures) relationship among the constructs. Overall, the discriminant validity for this measurement model and the three constructs was not fully supported which had strong relationship between constructs.

Thus, from CFA result, the new code of sustainability performance can be seen in Table 73

Tables 73 New Code Representing Sustainability Performance

No.	Component	Code	Indicator
1.	Environment	N2	Reduce freshwater consumption
2.	Environment	N3	Increase amount of recycled
3.	Environment	N4	Reduce energy in production

4.	Environment	S8	Improve balance of male to female rate
5.	Economic	E5	Increase the number of customers
6.	Economic	E6	Reduce customer complaints
7.	Economic	E8	Increase rate of new products
8.	Economic	E9	Increase R&D budget share
9.	Economic	E10	Increase overall equipment efficiency
10.	Economic	E15	Reduce maintenance hour
11.	Economic	E16	Increase the number of suppliers
12.	Economic	E17	Reduce stops caused by suppliers
13.	Economic	E18	Improve percent of suppliers w/o EHS
14.	Social	S5	Increase level of education
15.	Social	S7	Increase employee satisfaction rate
16.	Social	S13	Increase support employee health care

4.5.3 Overall Measurement Model

4.5.3.1 Assessment of Goodness-of-Fit of the Overall Measurement Model

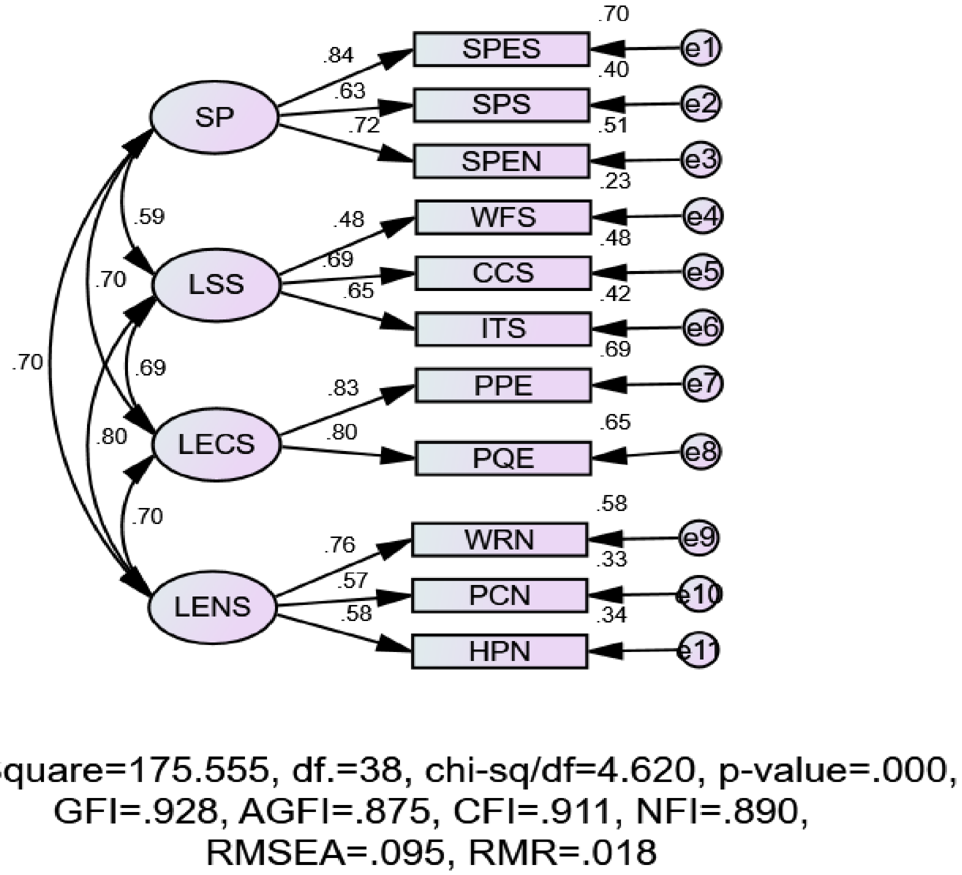
The measurement model for SEM analysis included the four focal constructs of the study, lean social sustainability (LSS), lean economic sustainability (LECS), lean environment sustainability (LENS), and sustainability performance (SP). After the measurement model of each research construct achieved the acceptable goodness-of-fit, the remaining 51 indicators along with 11 first-order factors were loaded on their respective constructs and performed by CFA to estimate the fit indices for the overall measurement model of summary on first-order factors as illustrated in Figure 26. The fit indices revealed that the initial estimation of CFA for perceived overall measurement model with eleven observed variables did not provide an appropriate fit to the sample data.

The result demonstrated χ^2/Df=4.620, GFI=0.928, CFI=0.911, NFI=0.890, RMSEA=0.095, RMR=0.018. There was a need for further modification that could affect χ^2/Df less than 3, NFI higher than 0.90, and RMSEA less than 0.07.

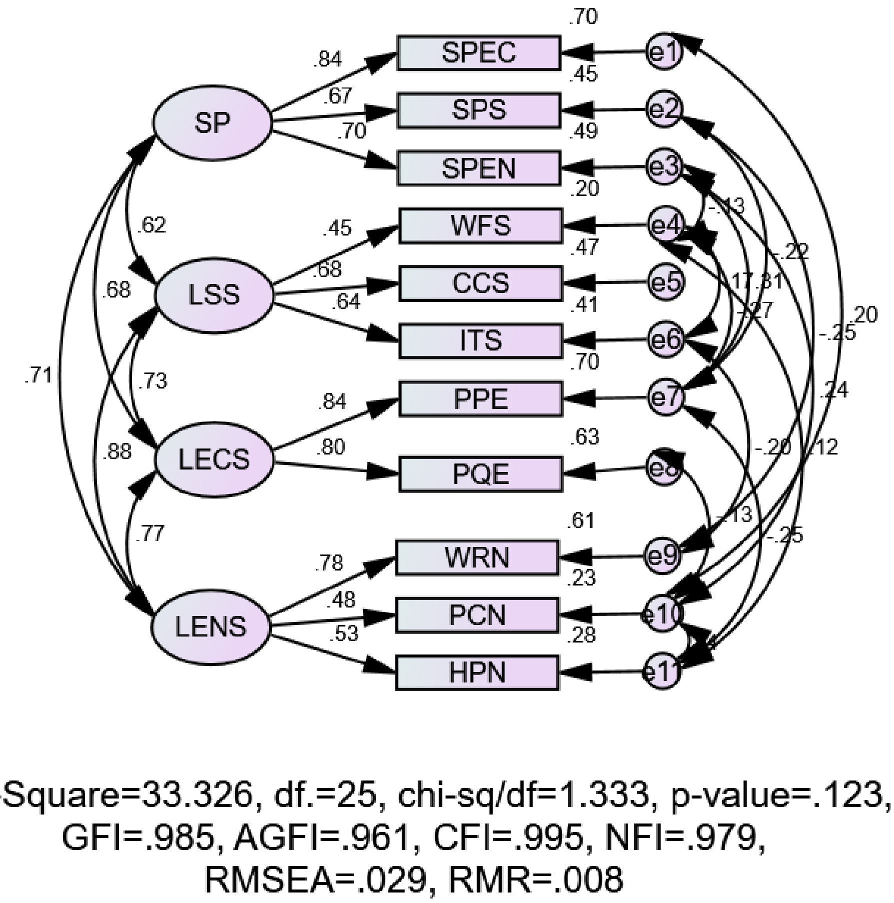
Tables 74 Goodness-of-Fit Indices Result for the Final Measurement Model Lean Sustainability

	χ^2	Df	p-value	χ^2/Df	GFI	CFI	NFI	RMSEA	RMR
Criteria	-	-	-	≤ 3.00	≥ 0.90	≥ 0.90	≥ 0.90	≤ 0.07	≤ 0.08
Initial model	175.555	38	.000	4.620	.928	.911	.890	.095	.018
Final model	33.326	25	.123	1.333	.985	.995	.979	.029	.008

After modification the result demonstrated that the full measurement model fit was satisfactory with χ^2/Df=1.333, GFI=0.985, CFI=0.995, NFI=0.979, RMSEA=0.029, RMR=0.008. There was no need for further modification. (Hair et al., 2014, Schumacker and Lomax, 2016)(see Figure 27)



Figures 25 Initial model of Overall measurement model



Figures 26 Final model of Overall measurement model

4.5.3.2 Discriminant validity and correlation matrix among four constructs

Discriminant validity refers to "the degree to which two conceptually similar concepts are distinct"(Hair et al., 2014). Specifically, the four constructs of the study should not be highly intercorrelated, correlation coefficient below 0.90, to confirm that each construct explains its indicators instead of other constructs in the model (Kline, 2011). This study utilized the criterion set by Formell and Larcker (1981) to test the discriminant validity of the four constructs. The relationship of each pair or the estimated correlation coefficients of latent constructs was compared with the square root of AVE (average variance extracted) of latent constructs. Thus, the estimated correlations among the four constructs should be lower than the square root of AVE to establish the discriminant (Hair Jr et al., 2016, Hair et al., 2011).

Tables 75 Discriminant validity and correlation matrix among the research constructs

Constructs	Mean	SD	LSS	LECS	LENS	SP
LSS	4.162	0.464	***.731***			
LECS	4.058	0.532	.767	***.942***		
LENS	4.155	0.451	.777	.784	***.686***	
SP	4.035	0.499	.620	.684	.737	***.875***

Note: *n*=300, SD = Standard deviation, LSS: Lean Social Sustainability, LECS: Lean Economic Sustainability, LENS: Lean Environment Sustainability, SP: Sustainability Performance, AVE: Average variance extracted, Diagonal figures in bold represent the square root of AVE of the latent variables.

As reported in Figure 27 and Table 75, the relationship between four constructs existed with the positive correlation coefficients from 0.620 (LSS and SP) to 0.737 (LENS and SP) indicating moderate to strong relationship among the constructs. The square roots of AVE (as-presented as the diagonal figures in bold in Table 75 of lean social sustainability practices LSS (0.731) and lean environment sustainability practices LENS (0.686) were lower than the estimated correlation coefficients (off-diagonal figures) relationship among the constructs while lean economic sustainability practices LECS (0.942) and sustainability performance (0.875) were greater than the estimated correlation coefficients (off-diagonal figures) relationship among the constructs. Overall, the discriminant validity for this measurement model and the four constructs was not fully supported which had strong relationship between constructs.

Tables 76 Result of Second order CFA for Modified Lean Sustainability and Sustainability Performance Model

Construct/Indicators	b	***t*-value**	**R^2**	**CR**	**AVE**
SP				**0.780**	**0.543**
SPEC	0.836	-	0.698896		
SPS	0.668	12.561	0.446224		
SPEN	0.697	13.381	0.485809		
LSS				**0.619**	**0.358**
WFS	0.448	-	0.200704		
CCS	0.683	7.278	0.466489		
ITS	0.638	7.795	0.407044		
LECS				***0.799***	**0.665**
PPE	0.835	-	0.697225		
PQE	0.796	14.76	0.633616		
LENS				***0.632***	**0.375**
WRN	0.782	-	0.611524		
PCN	0.481	8.609	0.231361		
HPN	0.531	9.375	0.281961		

Note: all indicators are significant at $p < 0.001$, the path of SPEC, WFS, PPE and WRN were fixed to 1 (not estimated). α = Cronbach's alpha coefficient, CR = construct reliability or composite reliability, AVE = average variance extracted.

4.5 Structural equation modeling: SEM

From the above explanation of results two-stage modelling process which involved a series of CFA, the final measurement model (revised model) from the sample data demonstrated that the measurement scales were a well-constructed according to SEM analysis of reliability and validity. In the second stage, SEM was conducted with the maximum likelihood to test the research hypotheses through AMOSv.22. The results of goodness-of-fit and the result of hypotheses testing of the structural model were presented in the next section.

4.5.1 Assessment for Goodness-of-Fit of the Structural Model

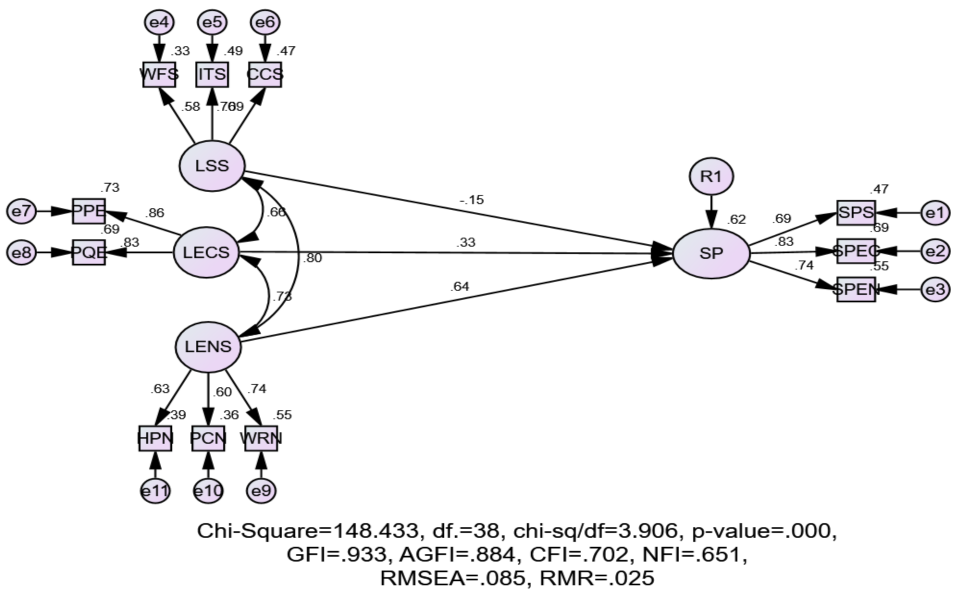
The structural model consisting of 1) Lean social sustainability there were three first-order constructs, work force (six indicators), information transparency (four indicators), community contribution (three indicators). 2) Lean economic sustainability there were two first-order constructs, physical productivity (five indicators), product quality (seven indicators). 3) Lean environment sustainability there were three first-order constructs, waste reduction (four indicators), process centered focus (three indicators), high people's involvement & participation (three indicators). 4) Sustainability performance there were three first-order constructs, economic performance (nine indicators), social performance (four indicators), environment (three indicators). The path among these four constructs was established as presented in Figure 28 for this structure equation model which is regarded as the hypotheses model of this study.

The testing goodness-of-fit of the structural model by separate three constructs and measuring total model found factor loading minus (-15) which opposite with literature of lean social sustainability effect to sustainability performance. (see Figure 28). In addition, when separated testing only lean social sustainability (LSS) to sustainability performance (SP) alone the goodness-of-fit of the structural model factor loading shown positive result 0.59 (see Figure 29). Thus, from the discriminant validity result having strong relationship among constructs, to combine of new grouping lean social sustainability (LSS), lean economic sustainability (LECS), and lean environment sustainability (LENS) to lean sustainability practices (LEAN) was suitable solution. After modification the result demonstrated that the full measurement model fit was satisfactory with χ^2/Df=1.273, GFI=0.985, CFI=0.980, NFI=0.919, RMSEA=0.026, RMR=0.010. (Hair et al., 2014, Schumacker and Lomax, 2016)(see Figure 30).

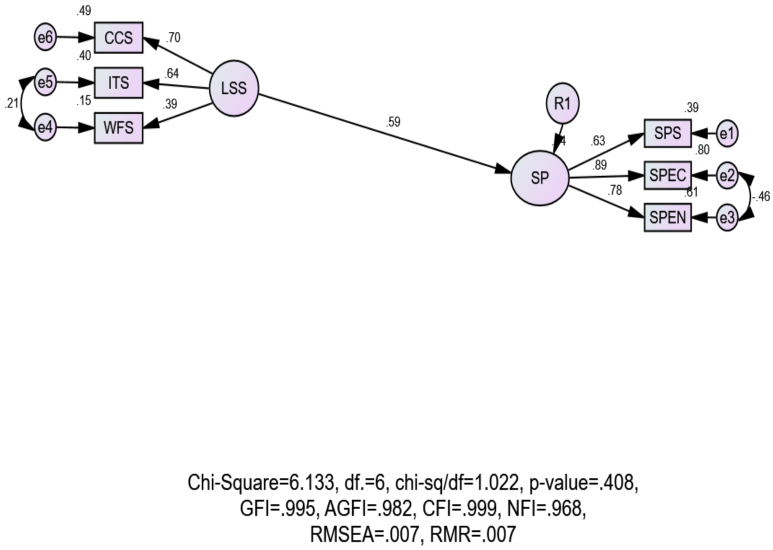
It should be noted that the result for the final measurement model lean sustainability and sustainability performance p-value=0.155 which above 0.05 different with recommended value of lower than 0.05, however other result demonstrated of model fit was satisfactory as above explanation. There was no need for further modification. (Anwar et al., 2018, Anwar et al., 2020)

Tables 77 Goodness-of-Fit Indices Result for the Final Measurement Model Lean Sustainability and sustainability performance

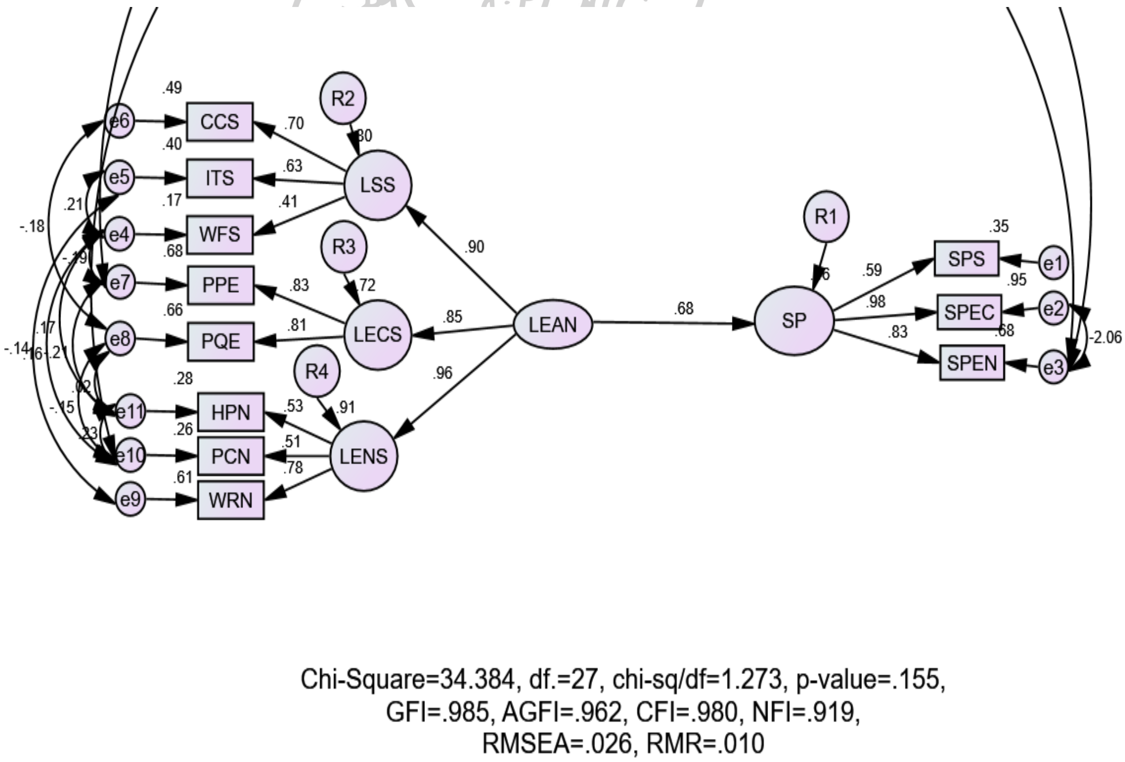
	χ^2	Df	p-value	χ^2/Df	GFI	CFI	NFI	RMSEA	RMR
Criteria	-	-	-	≤ 3.00	≥ 0.90	≥ 0.90	≥ 0.90	≤ 0.07	≤ 0.08
Initial model	148.433	38	.000	3.906	.933	.702	.651	.085	.025
Final model	34.384	27	.155	1.273	.985	.980	.919	.026	.010



Figures 27 Initial model of Overall measurement model



Figures 28 Initial model of one construct LSS measurement model



Figures 29 Final model of Overall measurement model

4.6 Hypotheses Testing

The second objective of this study is to investigate the interrelationships between sustainability lean tools and sustainability performance on the three dimensions of environment, economic and social. SEM with the maximum likelihood method was performed to estimate for the parameters of the four paths of the proposed hypothesized structural model as presented in Figure 31 to 34.

4.6.1 Hypothesis Testing of Direct Effect H1-H4

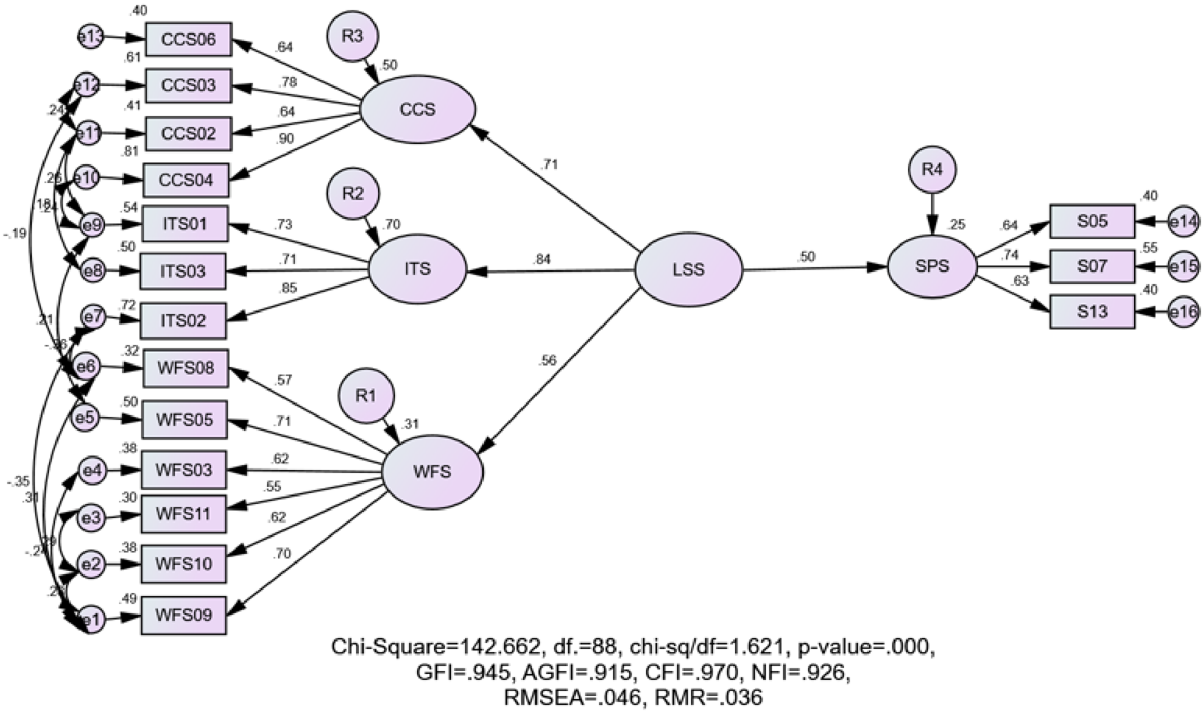
H1: Lean Social Sustainability has a positive impact on social sustainability performance.

Hypothesis 1 predicted that lean social sustainability LSS practices significantly influence social sustainability performance (SPS). The structural model as presented in Figure 31 Showed the path coefficient (β) of the independent variable lean social sustainability practices on SPS, the dependent variable. In this study, LSS practices were in the form of high-performance work practices manifested by work force participation, community contribution, and information transparency, while SPS represents social sustainability performance activities of increase level of education, increase employee satisfaction rate and increase support employee health care. As illustrated in Table 78 LSS practices perceived by SPS significantly influence (β= 0.50, t-value=4.517, p<0.001), confirming Hypothesis 1. This signifies that good LSS practices promote SPS performance.

Tables 78 presents the result of hypothesis 1 testing derived from SEM path analysis. The hypothesis was proved to be supported by data. (See Figure 31)

Hypotheses	β	**b**	**SE**	***t*-value**	**Results**
H1: LSS → SPS	0.50	0.876	0.194	4.517***	Supported

***p-value < .001



Figures 30 Final model of Hypothesis 1 testing

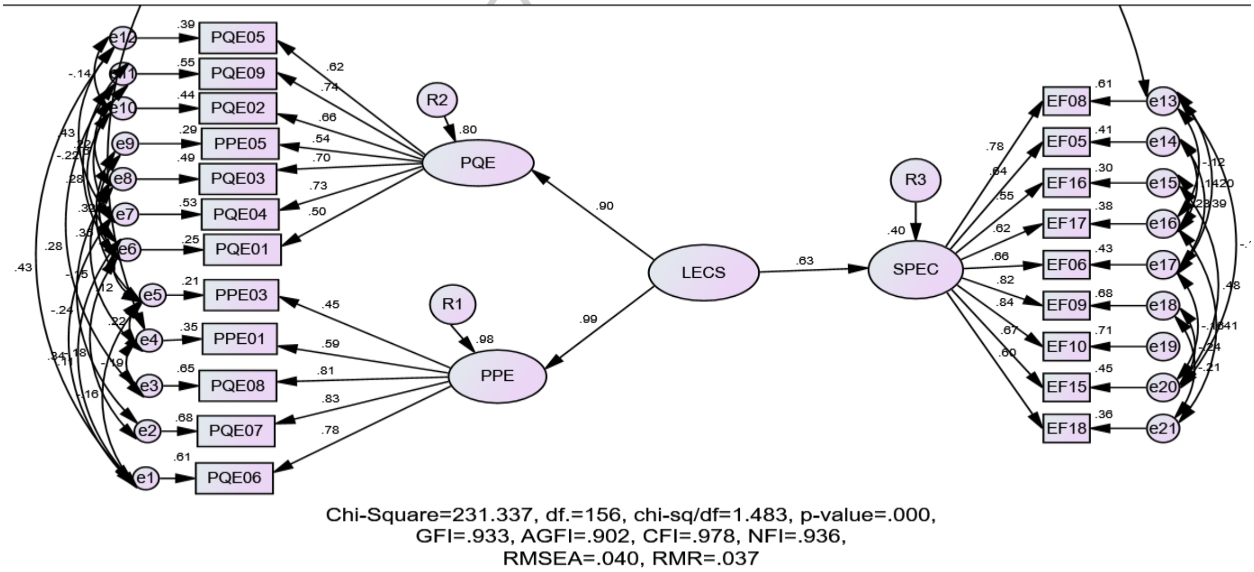
H2: Lean Economic Sustainability has a positive impact on economic sustainability performance.

Hypothesis 2 predicted that lean economic sustainability LECS practices significantly influence economic sustainability performance (SPEC). The structural model as presented in Figure 32 Showed the path coefficient (β) of the independent variable lean economic sustainability practices on SPEC, the dependent variable. In this study, LECS practices were in the form of high-performance work practices manifested by physical productivity, and product quality, while SPEC represents economic sustainability performance activities of increase the number of customers, reduce customer complaints, increase rate of new products, increase R&D budget share, increase overall equipment efficiency, reduce maintenance hour, increase the number of suppliers, reduce stops caused by suppliers and improve percent of suppliers without EHS. As illustrated in Table 79, LECS practices perceived by SPEC significantly influence ($\beta = 0.629$, $t=9.777$, $p<0.001$), confirming Hypothesis 2. This signifies that good LECS practices promote SPEC performance.

Tables 79 presents the result of hypothesis 2 testing derived from SEM path analysis. The hypothesis was proved to be supported by data. (See Figure 32)

Hypotheses	β	b	SE	*t*-value	Results
H2: LECS □ SPEC	0.629	0.686	0.07	9.777***	Supported

***p-value < .001



Figures 31 Final model of Hypothesis 2 testing

H3: Lean Environment Sustainability has a positive impact on environment sustainability performance.

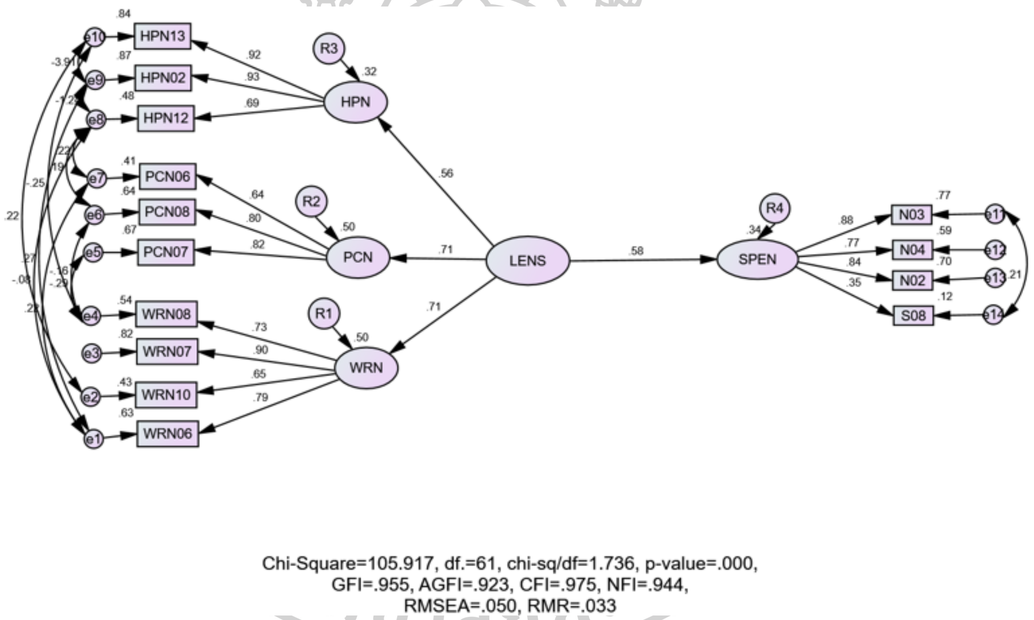
Hypothesis 3 predicted that lean environment sustainability LENS practices significantly influence environment sustainability performance (SPEN). The structural model as presented in Figure 33 Showed the path coefficient (β) of the independent variable lean environment sustainability practices on SPEN, the dependent variable. In this study, LENS practices were in the form of high-performance work practices manifested by waste reduction, process center focus, and high level of people involvement and participation, while SPEN represents environment sustainability performance activities of reduce freshwater consumption, increase amount of recycled, reduce energy in production, and improve balance of male to female rate. As illustrated in Table 80 LENS practices perceived by SPEN significantly influence (β= 0.579, t -value=6.501, p<0.001), confirming Hypothesis 3. This signifies that good LENS practices promote SPEN performance**.**

Tables 80 presents the result of hypothesis 3 testing derived from SEM path analysis.

The hypothesis was proved to be supported by data. (See Figure 33)

Hypotheses	β	**b**	**SE**	***t*-value**	**Results**
H3: LENS ⟶ SPEN	0.579	0.931	0.143	6.501***	Supported

***p-value < .001



Figures 32 Final model of Hypothesis 3 testing

H4: Lean Sustainability has a positive impact on sustainability performance.

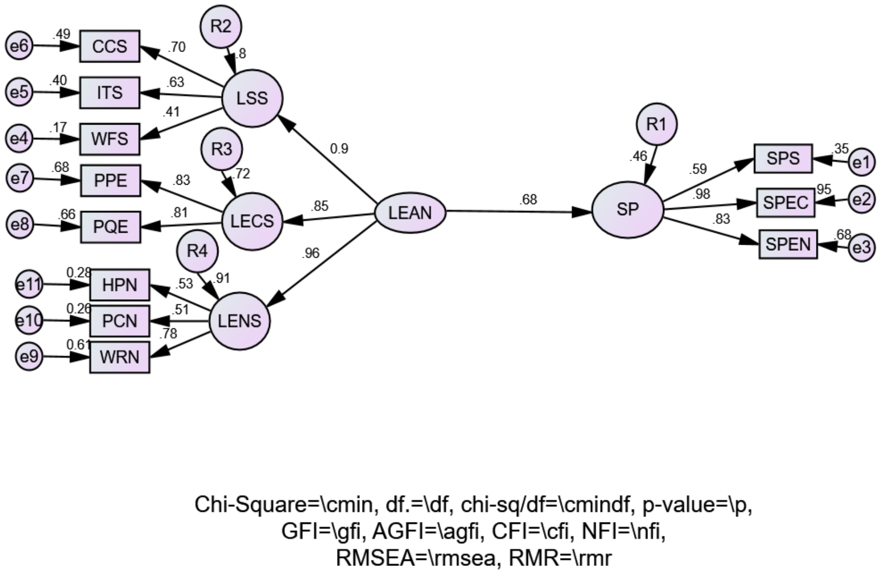
Hypothesis 4 predicted that lean sustainability Lean manufacturing significantly influence sustainability performance (SP). The structural model as presented in Figure 34 Showed the path coefficient (β) of the independent variable lean environment sustainability practices on SP, the dependent variable. In this study, Lean manufacturing were in the form of high-performance work practices manifested by lean social sustainability practices, lean economic sustainability practices, and lean environment sustainability practices, while SP represents sustainability performance activities of social sustainability performance, economic sustainability performance, and environment sustainability performance. As illustrated in Table 81, Lean manufacturing perceived by SP significantly influence (β= 0.678, t=5.263, p<0.001), confirming Hypothesis 4. This signifies that good Lean manufacturing promote SP performance.

Tables 81 presents the result of hypothesis 4 testing derived from SEM path analysis.

The hypothesis was proved to be supported by data. (See Figure 34)

Hypotheses	**β**	**b**	**SE**	***t*-value**	**Results**
H4 : → SP LEAN	0.678	1.166	0.222	5.263***	Supported

***p-value < .001



Figures 33 Final model of Hypothesis 4 testing

Tables 82 Hypothesis Testing Results

No.	Hypothesis	Result
H1:	Lean Social Sustainability has a positive impact on social sustainability performance.	Accepted
H2:	Lean Economic Sustainability has a positive impact on economic sustainability performance.	Accepted
H3:	Lean Environment Sustainability has a positive impact on environment sustainability performance.	Accepted
H4:	Lean Sustainability has a positive impact on sustainability performance.	Accepted

4.7 Chapter Summary

This chapter presents the empirical results both in descriptive statistics and inferential statistics. The data (n=406) was initially assessed for the normality. The data (n=106) was assessed a series of the exploratory factor analysis (EFA) and the reliability Cronbach's alpha. Then the data (n=300) a series of confirmatory factor analysis (CFA) second-order was performed for each construct together with discriminant validity and correlation matrix as well as the overall measurement model and modified to achieve the model fit for all data (n=406). The construct validity for all measurement scales was supported. Then, structural equation modelling (SEM) was performed and demonstrated that the structural model achieved the model fit with the results of hypotheses testing. The hypothesis was confirmed. Thus, the final chapter will discuss the empirical findings and explain the conclusion for the study, including research implication, contribution, limitation and future research.

CHAPTER 5

DISCUSSION AND CONCLUSION

This chapter presents the overview of the study, summary of study finding, discussion of research findings, research contributions, and limitations and future research recommendations.

5.1 Overview of Study

This study applies the quantitative investigation, mainly to accomplish the following research objectives: 1) to develop the measurement scale of lean manufacturing applied in social, economic and environment sustainability dimensions; 2) to examine the effects of lean manufacturing applied in social, economic and environment sustainability dimensions on sustainability performances; 3) to identify the contributions and implications of the research findings in the multinational companies (MNCs). To achieve these objectives, the research instrument was used in accordance with the research methods. The employed research instrument in the quantitative study was a questionnaire containing question items obtained from development based on issues highlighted in previous literature. There were 149 question items covering four aspects in lean social sustainability, lean economic sustainability, lean environment sustainability and sustainability performance. The respondents were to respond to those question items by checking their answers in a five-point Likert scale for all dimensions of sustainability lean manufacturing and social sustainability performance. The scale ranges from 1 to 5 which refer as "strongly disagree" for 1 and "Strongly agree for 5. Content validity of the questionnaire items, as verified by 5 experts, showed the IOC index of not lower than 0.50 for every item accompanied by a pre-testing administered with 30 samples to test on whether the questionnaire was adequately valid and reliable.

The population of this study consists of all manufacturing firms who implement lean manufacturing in Thailand automotive. The province includes Bangkok, Ayuthaya, Samutprakarn, Chonburi, Pathumthani, Rayong, Lampoon, Prachinburi. The 'MNCs firm' here refers to companies as well as individual units or sites within the companies. The total response 406 questionnaire both by email and return paper questionnaires that the appropriate sample size for SEM analysis (Guadagnoli and Velicer, 1988, Molwus et al., 2013), and the proper criterion that Lomax and Schumacker (Schumacker and Lomax, 2016) indicated for the sample size is between 250-500.

The population frame for this study is obtained from Thai Autoparts Manufacturers Association (TAPMA) directory 2020, Electrical, electronic, metal, plastic, rubber, and other vehicle components are all represented on the list of manufacturing companies. The manufacturing businesses in this study were divided into three categories of Thai owner 100 percent, Foreign owner 100 percent and Thai &Foreign owners. This research integrates concerns of sustainability, with an emphasis on lean social sustainability and operational aspects of lean adoption. As a result, key informants in manufacturing organizations who occupy management positions are the most relevant responders. Sustainable manufacturing with a focus on environmental effects has been explored in this study which identify by quality system certification obtain in their firm at least ISO 9001 and ISO14001 or ISO26000 or OHSAS 18001or ISO45001.

After the collection of data was completed, the statistical analysis was then performed with descriptive and inferential methods. The descriptive statistical method was used to give overall details about demographic data of the samples, along with the respondent's interpreted level of practice in each individual section. The reliability of the questionnaire, as represented by Cronbach's alpha coefficient to test questionnaire provides appropriate reliability for respondents (Ursachi, Horodnic et al. 2015). The inferential statistical method was applied by testing hypotheses. The factor analysis was conducted in all measurement models. The EFA was performed by using the principal components method together with the Varimax rotation and using SPSS software with 106 sample to all constructs of lean social sustainability, lean economic sustainability, lean environment sustainability, and sustainability performance to identify which components had cross-loadings greater than 0.40 and had factor loadings below 0.40 (Hair, et. al., 2010) to decide to excluded those components. The analysis result revealed three first-order components of lean social sustainability namely 1) work force, 2) information transparency, and 3) community contribution which the second-order revealed six items remain for work force component, three items remain for information transparency, and four items remain for community contribution. For the first-order components of lean economic sustainability, the analysis result revealed two components namely 1) physical productivity, and 2) product quality which the second-order revealed five items remain for physical productivity, and seven items remain for product quality component. For the first-order components of lean environment sustainability, the analysis result revealed three components namely 1) waste reduction, 2) process center focus, and 3) high people involvement which the second-order revealed seven items remain for waste reduction, and four items remain for process center focus, and three items remain for high people involvement component. Finally, For the first-order components of sustainability performance, the analysis result revealed three components namely 1) environment performance, 2) economic performance, and 3) social performance which the second-order revealed three items remain for environment performance, and nine items remain for economic performance, and six items remain for social performance component. Worthington and Whittaker (2006) recommended starting with EFA, and then moving to CFA using a different sample. When the EFA process was finished, the CFA was employed thereafter with all four constructs by using AMOS software to test overall goodness of fit in each individual measurement model with 300 sample next after first 106 sample used in EFA to all constructs of lean social sustainability, lean economic sustainability, lean environment sustainability, and sustainability performance.

5.2 Summary of Research Findings

This section summarizes the three key points of the research questions in chapter one. According to the level of lean sustainability practices of all three dimensions of environment, economic and social, and sustainability performance of automotive manufacturing firms. Briefly, the overall mean score of all five constructs is at high level (3.99 to 4.17). The study finding demonstrated a high level of perception to an overall of lean social sustainability practice ($\bar{x}$=4.164). Considering in individual aspect, it is shown that all high level of practices can be found in three dimensions: Work force ($\bar{x}$=4.165), Information transparency ($\bar{x}$=4.154), and Community contribution ($\bar{x}$=4.168).

For lean economic sustainability practices finding a high level of perception ($\bar{x}$=4.072), which the two dimensions are shown HIGH level of practices of: Physical productivity($\bar{x}$=3.998), and Product quality ($\bar{x}$=4.113). For lean environment sustainability practices finding a HIGH level of perception ($\bar{x}$=4.150), which the three dimensions are shown high level of practices of: Waste reduction ($\bar{x}$=4.138), Process centered focus ($\bar{x}$=4.141), and High level of people involvement and participation ($\bar{x}$=4.171). For sustainability performance practices finding a high level of perception ($\bar{x}$=4.036), which the three dimensions are shown high level of practices of: Social sustainability performance ($\bar{x}$=4.002), Economic sustainability performance ($\bar{x}$=4.013), and Environment sustainability performance ($\bar{x}$=4.108). There was no attribute found in the level of very high, moderate, low and very low level.

5.3 Discussion of Research Findings and to answer to research question II : What is the measurement scale of Lean manufacturing applied in social, economic and environment sustainability dimensions?

5.3.1 The construct of lean sustainability practices and sustainability performance practices of MNCs.

From total three constructs of lean sustainability, First, lean environment sustainability (LENS), from literature, there are three principles of lean and environmental refer to literature review of chapter 2 a) Principle of Waste Reduction b) Process-centered focus and c) High levels of people involvement and participation. (Martínez-Jurado and Moyano-Fuentes, 2014). After the final result of the model fit, total three constructs are confirmed which the item of practice related to each construct can be explained from the final outcome by following

a) Principle of Waste Reduction (WRN), the result of final constructs confirm the lean environment sustainability practices in Thai automotive firms that 1) TPM activity reduce waste and cost, and the benefits of TPM in lean and sustainability are helping the firm in focuses on wastes reduction and cost down activities (Piercy and Rich, 2015). The consequences of operating TPM are increasing equipment lifespan reduces the need for replacement and the related environmental consequences, as well as the quantity and severity of spills, leaks, and upset conditions: There will be less solid and hazardous waste (Fliedner, 2008). 2) Kanban practice reduces waste and scrap, in the way of helping the firm in regularize system cost and the consequences of operating Kanban is reduce material waste as material will not be manufactured or transported unless a client requests it..(Piercy and Rich, 2015). Furthermore, the Kanban method saves money by decreasing inventory stock levels and overhead expenses by eliminating overproduction, establishing flexible work stations, reducing waste and scrap, minimizing waiting times and logistics costs, and reducing waste and scrap (Gupta et al., 1999). 3) POUS reduce waste of non-value activities such as motion and transport. Safe cost and reduce waste of non-value activities (Kilpatrick, 2003) (Alukal, 2003). 4) Continuous flow reduces scrap or backflows since there are no stoppages, scrap, or backflows as the product progresses from concept to launch, order to delivery, and raw materials into the hands of the customer" (Womack and Jones, 1997).

b) Process-centered focus (PCS), the result of final constructs confirm the lean environment sustainability practices in Thai automotive firms that 1) TPM in continuous improvement target improve the effectiveness of the transformation process and continuous improvement that the company can target and making it as part of the day-to-day operation (McCarthy and Rich, 2004). 2) Kanban cards pull material focus on entire process of value stream such as the Kanban in pattern production often this style of production is needed (www.lean.org).3) Heijunka working together balance fashion as no one waiting so everyone working together (Rother and Harris, 2001).

c) High levels of people involvement and participation (HRN), the result of final constructs confirm the lean environment sustainability practices in Thai automotive firms that 1) 5S gain creative input from staff which giving them an opportunity to provide creative input (Kilpatrick, 2003) and monitored, evaluated and continuously improved a comprehensive cleaning, removing dirt sources and simplifying the cleaning procedure (Filip and Marascu-Klein, 2015). 2) POUS involve employee to kept which help to reduce non-value activities such as motion and transport (Kilpatrick, 2003, Alukal, 2003). 3) Continuous flow worker better perform in so that they may be completed more effectively and handled more simply, activities should be categorized by kind (Womack and Jones, 1997).

Second, lean economic sustainability (LECS), from literature, there are two principles of lean and economic sustainability refer to literature review of chapter 2 a) Physical productivity Principle- Units per labor hour b) Product quality – Defect unit. After the final result of the model fit, total two constructs are confirmed which the item of practice related to each construct can be explained from the final outcome by following

a) Physical productivity Principle- Units per labor hour (PPE), the result of final constructs confirms the lean economic sustainability practices in Thai automotive firms, there are five activities 1) the practice of SMED is also describe physical productivity confirmed by literature that smaller batch sizes necessitate more frequent setups. As a result, decreasing setup time (and cost) is becoming increasingly important in order to service consumers in a timely and profitable manner (Piercy and Rich 2015). 2) Regarding suggests the concept of "lean" to existing local suppliers rather than finding new, lean-applied suppliers also mention by (Liker 1997),(Wu and Management 2003),(Krause, Scannell et al. 2000) is that much of the research on Japanese cooperative supply partnerships is predicated on the idea that they are formed to improve some element of supplier manufacturing performance.. It should be noted that there are three of activities (SPC quality improvement technique, DOE quality improvement technique, and cause and effect or affinity diagram) that original literature was from product quality but result is rotated in physical productivity component. According to the literature 3) SPC, 4) DOE and 5) Cause and Effect can contribute not only improve product quality but also productivity of the end process result. (Kimura and Kiyota 2004, Srinivasu, Reddy et al. 2011, Jamil, Khalid et al. 2018). Therefore, these three practices can combine to describe physical productivity as new measurement constructs.

b) Product quality – Defect unit (PQE), the result of final constructs confirms the lean economic sustainability practices in Thai automotive firms, there are seven activities and one of them 1) Tracking supplier productivity performance that original literature was from physical productivity principle but result is rotated in product quality component According to the literature The assembler and the supplier collaborate on every element of the supplier's manufacturing process, looking for cost-cutting and quality-improvement opportunities (Womack, Womack et al. 1990),(Lamming and Hampson 1996). In this mention the factory aims to improve supplier in term of cost reduction which positive effect on physical productivity, however not only cut cost is not overall expectation but also product quality needs to be improved. Thus, tracking supplier’s cost-effective solution also reasonable and has positive effect to product quality. There are three practices with suppliers are positive effect on product quality dimension including 2) regularly monitors suppliers’ overall waste reduction, 3) quality improvement and innovation performance, 4) provides training and teaching to suppliers to improve economic practice targets, and 5) provides incentives to suppliers to implement economic practices targets. Refer to the literature which importantly, several competitive elements of a buying firm's business strategy, including cost, quality, technology, delivery, flexibility, and profits, are directly influenced (both positively and negatively) by suppliers. (Handfield and Nichols Jr 1999),(Krause, Scannell et al. 2000). In addition, there are three practices in lean economic sustainability of quality improvement technique, 6) failure mode and effect analysis tool (“FMEA”), and 7) quality improvement (“QI”) that have positive effect on product quality which refer from literature.

Third, lean social sustainability (LSS), from literature, there are three principles of lean and social sustainability refer to literature review of chapter 2 a) Work force, b) Information Transparency, and c) Community Contribution. After the final result of the model fit, total three constructs are confirmed which the item of practice related to each construct can be explained from the final outcome by following

a) Work force (WFS), the result of final constructs confirms the lean social sustainability practices in Thai automotive firms, there are six activities 1) standardized work forms a baseline for kaizen to take specific interest in what process operators have to go through to make the process successful.(Dennis 2007) (Panizzolo 1998, Fliedner 2008, Piercy and Rich 2015). 2) As well as if company try to find the best ways of operating in safety condition from standard methods used with production rate (takt time, cycle time, work sequence). 3) The visual management practice improve safety working the equipment stop when a problem arises, a single operator can visually monitor and efficiently control many machines because of the visual management. (Shingo 1986, Monden 1998). 4) 5 whys technique if the company uses to analyze phase approach to problem solving promotes deep thinking through questioning to applied to most problems to engage workers finding solutions of problems. 5) Because of using 5 whys technique in problem solving the company can increase cross-skill of workers to work across plant. (Ohno 1988, Panizzolo 1998, Piercy and Rich 2015). and finally, 6) cross functional team work with working muti-functional involvement in continuous quality improvement programs to improve firms' performances. (Panizzolo 1998, Fliedner 2008, Piercy and Rich 2015).

b) Information transparency (ITS), the result of final constructs confirms the lean social sustainability practices in Thai automotive firms, there are three activities. 1) charitable giving to incentivize staff for improvement and in sustainability benefit positive member of community. This related to the positive impact of the organization in the community in which they operated.(Panizzolo 1998, Womack, Jones et al. 2003). 2) disclose to employee practice by company to understand cost/benefits to help them improvement in their work areas. (Panizzolo 1998). 3) the practice of sustainability audit at the company to public disclosure of activities and having a clear and written ethics policy, and ensuring legal compliance.

c) Community contribution (CCS), the result of final constructs confirms the lean social sustainability practices in Thai automotive firms, there are four activities 1) Employee participation in community and civic affaire as the company. 2) Explicit part of the strategy setting process to maintain a positive reputation in the local community to have charitable donation or positively. 3) A clear performance metrics practice to maintain a positive reputation in the local community. 4) The practice to dedicated to raising standards of health, education, product safety, workplace safety and prosperity. (Lamming and Hampson 1996, Womack, Jones et al. 2003, Kaptein 2004, Waddock and Governance in Global Business 2005, Piercy and Rich 2015).

Finally, sustainability performance (SP), In this research the selection of framework considering the directly applicable at factory level and focus on measuring shop floor, production managers and available of a suitable set of indicators for measuring sustainability progress and the indicators are comparable between factories (Winroth, 2016) and The most cited work on SPIs is the study by (Veleva and Ellenbecker, 2001). There are three principles of sustainability performance refer to literature review of chapter 2 a) Environment performance, b) Economic performance, and c) Social performance. After the final result of the model fit, total three constructs are confirmed which the item of practice related to each construct can be explained from the final outcome by following

a) Environment sustainability performance (SPEN) the result of final constructs confirms the environment sustainability performance in Thai automotive firms, there are four activities 1) Reduce freshwater consumption, 2) Increase amount of recycled, 3) Reduce energy in production, and 4) Improve balance of male to female rate. It should be noted that the last performance to improve balance of male to female originally of literature from social sustainability performance but result is rotated in environment sustainability productivity component.

b) Economic sustainability performance (SPEC) the result of final constructs confirms the environment sustainability performance in Thai automotive firms, there are nine activities 1) Increase the number of customers, 2) Reduce customer complaints, 3) Increase rate of new products, 4) Increase R&D budget share, 5) Increase overall equipment efficiency, 6) Reduce maintenance hour, 7) Increase the number of suppliers, 8) Reduce stops caused by suppliers, and 9) Improve percent of suppliers without EHS.

c) Social sustainability performance (SPS) the result of final constructs confirms the environment sustainability performance in Thai automotive firms, there are three activities 1) Increase level of education, 2) Increase employee satisfaction rate and, 3) Increase support employee health care. The overall construct as new measurement scale of lean sustainability practices and sustainability performance of automotive manufacturing firms shows in Table 83

Tables 83 Overall lean sustainability and sustainability performance new measurement scale

No.	Component	Code	Indicator
Lean Environment Sustainability Practices (LENS)			
1.	Waste Reduction	WRN6	TPM reduce waste and cost
2.	Waste Reduction	WRN7	Kanban practice reduces waste and scrap
3.	Waste Reduction	WRN8	POUS reduce waste of non-value job
4.	Waste Reduction	WRN10	Continous flow reduce scrap
5.	Process Center Focus	PCN6	TPM in continuous improvement target
6.	Process Center Focus	PCN7	Kanban cards pull material
7.	Process Center Focus	PCN8	Heijunka working together balance
8.	High People Involve	HPN2	5S gain creative input from staff
9.	High People Involve	HPN12	POUS involve employee
10.	High People Involve	HPN13	Continuous flow worker better perform
Lean Economic Sustainability Practices (LECS)			
1.	Physical Productivity	PPE1	SMED reduce cost of production
2.	Physical Productivity	PPE3	Existing supplier's approach
3.	Physical Productivity	PQE6	SPC quality improvement technique
4.	Physical Productivity	PQE7	DOE quality improvement technique
5.	Physical Productivity	PQE8	Cause and effect or affinity diagram
6.	Product Quality	PPE	Tracking supplier productivity
7.	Product Quality	PQE1	Monitoring supplier quality
8.	Product Quality	PQE2	Supplier training to meet econ target
9.	Product Quality	PQE3	Provide incentives to suppliers

10.	Product Quality	PQE4	Process management of quality improve
11.	Product Quality	PQE5	FMEA quality improvement technique
12.	Product Quality	PQE9	Establish quality culture

Lean Social Sustainability Practices (LSS)

1.	Work Force	WFS3	Standardized work reduce variations
2.	Work Force	WFS5	Standardize work product improve safety
3.	Work Force	WFS8	Visual Management improve safety
4.	Work Force	WFS9	5 why engage workers improve
5.	Work Force	WFS10	5 why increase cross-skill
6.	Work Force	WFS11	Cross functional team engage employees
7.	Information Transparency	ITS1	Charitable giving
8.	Information Transparency	ITS2	Transparency to employee
9.	Information Transparency	ITS3	Sustainability audit and public disclosure
10.	Community Contribution	CCS2	Employee participate in community
11.	Community Contribution	CCS3	Charity donations
12.	Community Contribution	CCS4	Clear performance metrics of reputation
13.	Community Contribution	CCS6	Dedicates to local community

Sustainability Performance (SP)

1.	Environment	N2	Reduce freshwater consumption
2.	Environment	N3	Increase amount of recycled
3.	Environment	N4	Reduce energy in production
4.	Environment	S8	Improve balance of male to female rate
5.	Economic	E5	Increase the number of customers

6.	Economic	E6	Reduce customer complaints
7.	Economic	E8	Increase rate of new products
8.	Economic	E9	Increase R&D budget share
9.	Economic	E10	Increase overall equipment efficiency
10.	Economic	E15	Reduce maintenance hour
11.	Economic	E16	Increase the number of suppliers
12.	Economic	E17	Reduce stops caused by suppliers
13.	Economic	E18	Improve percent of suppliers w/o EHS
14.	Social	S5	Increase level of education
15.	Social	S7	Increase employee satisfaction rate
16.	Social	S13	Increase support employee health care

5.3.2 Research question I: How the Lean manufacturing applied in social, economic and environment sustainability dimensions affect sustainability performances?

Prior confirm all data were appropriate for confirmatory factor analysis (CFA) to examine the reliable indicators of each construct. After the measurement model of each research construct achieved the acceptable goodness-of-fit, the remaining 51 indicators along with 11 second-order factors were loaded on their respective constructs. Additionally, none of these indicators and second-order factors were eliminated after performing structural equation modeling (SEM). The results of CFA in all four constructs demonstrated acceptable model fit indices with statistically significant standardized estimates excepted two components for lean environment sustainability and sustainability performance were need further modification. Until the final result demonstrated acceptable model fit indices for lean environment sustainability which the second-order excluded three items and remain four items for waste reduction, and excluded one item and remain three items for process center focus component. In addition, for sustainability performance component, the final result demonstrated acceptable model fit indices for sustainability performance which the second-order excluded two items and remain sixteen items for social performance component. As the final results of CFA in all four constructs demonstrated acceptable model fit indices with statistically significant standardized estimates were as shown as follows:

1) Lean social sustainability (LSS): χ^2/Df=1.164, GFI=0.971, CFI=0.995, NFI=0.965, RMSEA=0.023, RMR=0.025.

2) Lean economic sustainability (LECS): χ^2/Df=1.215, GFI=0.978, CFI=0.996, NFI=0.978, RMSEA=0.027, RMR=0.020

3) Lean environment sustainability (LENS): χ^2/Df=1.129, GFI=0.982, CFI=0.997, NFI=0.978, RMSEA=0.021, RMR=0.022. (after four items were removed WRN 04, WRN11, WRN15, PCN15).

4) Sustainability performance (SP): χ^2/Df=1.062, GFI=0.968, CFI=0.998, NFI=0.970, RMSEA=0.014, RMR=0.024 (after two times were removed S01 and S02).

For the measurement model for SEM analysis included the four focal constructs of the study, lean social sustainability (LSS), lean economic sustainability (LECS), lean environment sustainability (LENS), and sustainability performance (SP), the good fit indices and cutoff points used in this study were χ^2/Df=1.333, GFI=0.985, CFI=0.995, NFI=0.979, RMSEA=0.029, RMR=0.008. Referring to the hypothesis testing through path analysis, it was discovered that the hypothesis of this study is supported by the empirical data as evidenced in table 80 to 83.

Based on the testing results, the causal-effect relationship between variable can be summarize as follow

(1) Lean Social Sustainability and Social Sustainability Performance

SEM was utilized to examine the causal relationship of these three independent variables of work force (WFS), community contribution (CCS), and information transparency (ITS) to social sustainability performance (SPS). The result confirmed that the total framework of lean social sustainability practices had direct effects of social sustainability performance. The results of hypothesis testing will be mainly discussed in this chapter to address the main objective of this study. Good model fit indices confirmed the theoretical model of the full measurement model fit was satisfactory with χ^2/Df=1.621, GFI=0.945, CFI=0.970, NFI=0.926, RMSEA=0.046, RMR=0.036 according to overall the discriminant validity for this measurement model and the three constructs was fully supported which had strong relationship among constructs.

According to the above model, the empirical result suggests that practicing lean social sustainability (LSS) can influence social sustainability performance (SPS) a direct relationship and supporting Hypothesis 1 of factor loading (0.50) in the SEM indicates an exceeding the suggested level (>0.50). The result is consistent with previous researchers of lean social sustainability and social sustainability performance positive relation as mention in literature review chapter 2. Among three constructs of lean social sustainability, information transparency ITS practices result shows the highest effect of factor loading (0.84) the practice and factor loading after the final result of the model fit are 1) Transparency to employee ITS02 (0.85), 2) Charitable giving ITS01 (0.73), and 3) Sustainability audit and public disclosure ITS03 (0.71) respectively.

The next construct is community contribution CCS practices result of factor loading (0.71) the practice and factor loading after the final result of the model fit are 1) Clear performance metrics of reputation CCS04 (0.90), 2) Charity donations CCS03 (0.78), 3) Dedicates to local community CCS06 (0.64), and 4) Employee participate in community CCS02 (0.64) respectively. The last construct is work force WFS practices result of factor loading (0.56) the practice and factor loading after the final result of the model fit are 1) Standardize work production improve safety WFS05 (0.71), 2) 5 why engage workers improve workplace WFS09 (0.70), 3) Standardized work reduce variations WFS03 (0.62), 4) 5 why increase cross-skill WFS10 (0.62), 5) Visual Management improve safety WFS08 (0.57), and 6) Cross functional team engage employees WFS11 (0.55), respectively. The practice and factor loading of SPS after the final result of the model fit are 1) Increase employee satisfaction rate S07 (0.74), 2) Increase level of education S05 (0.64), and 3) Increase support employee health care S13 (0.63), respectively.

(2) Lean Economic Sustainability and Economic Sustainability Performance

SEM was utilized to examine the causal relationship of these two independent variables of physical productivity (PPE), and product quality (PQE) to economic sustainability performance (SPEC). The result confirmed that the total framework of lean social sustainability practices had direct effects of social sustainability performance. The results of hypothesis testing will be mainly discussed in this chapter to address the main objective of this study. Good model fit indices confirmed the theoretical model of the full measurement model fit was satisfactory with χ^2/Df=1.483, GFI=0.933, CFI=0.978, NFI=0.936, RMSEA=0.040, RMR=0.037 according to overall the discriminant validity for this measurement model and the two constructs was fully supported which had strong relationship between constructs. According to the above model, the empirical result suggests that practicing lean economic sustainability (LECS) can influence economic sustainability performance (SPEC) a direct relationship and supporting Hypothesis 2 of factor loading (0.63) in the SEM indicates an exceeding the suggested level (>0.50). The result is consistent with previous researchers of lean social sustainability and social sustainability performance positive relation as mention in literature review chapter 2. Between two constructs of lean economic sustainability, physical productivity PPE practices result shows the highest effect of factor loading (0.99) the practice and factor loading after the final result of the model fit are 1) DOE quality improvement PQE07 (0.83), 2) Cause and effect or affinity PQE08 (0.81), 3) SPC quality improvement PQE06 (0.78), 4) SMED reduce cost of production PPE01 (0.59) and 5) Existing supplier's approach PPE03 (0.45) respectively.

The next construct is product quality practices result of factor loading (0.90) the practice and factor loading after the final result of the model fit are 1) Establish quality culture PQE09 (0.74), 2) Process management of quality improve PQE04 (0.73), 3) Provide incentives to suppliers PQE03 (0.70), 4) Supplier training to meet economic target PQE02 (0.66), 5) FMEA quality improvement technique PQE05

(0.62), 6) Tracking supplier productivity performance PPE05 (0.54), and 7) Monitoring supplier quality improvement PQE01 (0.50) respectively.

The practice and factor loading of SPEC after the final result of the model fit are 1) Increase overall equipment efficiency E10 (0.84), 2) Increase R&D budget share E09 (0.82), 3) Increase rate of new products E08 (0.78), 4) Reduce maintenance hour E15 (0.67), 5) Reduce customer complaints E06 (0.66), 6) Increase the number of customers E05 (0.64), 7) Reduce stops caused by suppliers E17 (0.62), 8) Improve percent of suppliers without EHS E18 (0.60), and 9) Increase the number of suppliers E16 (0.55), respectively.

(3) Lean Environment Sustainability and Environment Sustainability Performance

SEM was utilized to examine the causal relationship of these three independent variables of waste reduction (WRN), process center focus (PCN), and high level of people involvement (HPC) to environment sustainability performance (SPEN). The result confirmed that the total framework of lean environment sustainability practices had direct effects of environment sustainability performance. The results of hypothesis testing will be mainly discussed in this chapter to address the main objective of this study. Good model fit indices confirmed the theoretical model of the full measurement model fit was satisfactory with χ^2/Df=1.736, GFI=0.955, CFI=0.975, NFI=0.944, RMSEA=0.050, RMR=0.033 according to overall the discriminant validity for this measurement model and the three constructs was fully supported which had strong relationship among constructs. According to the above model, the empirical result suggests that practicing lean environment sustainability (LENS) can influence environment sustainability performance (SPEN) a direct relationship and supporting Hypothesis 3 of factor loading (0.58) in the SEM indicates an exceeding the suggested level (>0.50). The result is consistent with previous researchers of lean environment sustainability and environment sustainability performance positive relation as mention in literature review chapter 2.

Among three constructs of lean environment sustainability, waste reduction WRN practices result and process center focus PCN show the highest effect of factor loading (0.71) the practice and factor loading of WRN after the final result of the model fit are 1) Kanban practice reduces waste and scrap WRN07 (0.90), 2) TPM reduce waste and cost WRN06 (0.79), 3) POUS reduce waste of non-value activities WRN08 (0.73), and 4) Continous flow reduce scrap or backflows WRN10 (0.66) respectively. The practice and factor loading of PCN after the final result of the model fit are 1) Kanban cards pull material PCN07 (0.82), 2) Heijunka working together balance fashion PCN08 (0.80), and 3) TPM in continuous improvement target PCN06 (0.64), respectively. The next construct is high level of people involvement HPN practices result of factor loading (0.56) the practice and factor loading after the final result of the model fit are 1) 5S gain creative input from staff HPN02 (0.93), 2) Continuous flow worker better perform HPN13 (0.92), and 3) POUS involve employee HPN12 (0.69), respectively. The practice and factor loading of SPEN after the final result of the model fit are 1) Increase amount of recycled N03 (0.88), 2) Reduce freshwater consumption N02(0.84), 3) Reduce energy in production N04 (0.77), and 4) Improve balance of male to female rate (0.35), respectively.

(4) Lean Sustainability and Sustainability Performance

SEM was utilized to examine the causal relationship of these four constructs. The result show that the discriminant validity output having strong relationship among constructs, to combine of new grouping lean social sustainability (LSS), lean economic sustainability (LECS), and lean environment sustainability (LENS) to lean sustainability practices (LEAN) was suitable solution. The result confirmed that the total framework of lean sustainability practices which consisted of all three dimensions of environment, economic and social practices had direct effects of sustainability performance. The results of hypothesis testing will be mainly discussed in this chapter to address the main objective of this study. Good model fit indices confirmed the theoretical model of the full measurement model fit was satisfactory with χ^2/Df=1.273, GFI=0.962, CFI=0.980, NFI=0.919, RMSEA=0.026, RMR=0.010 after combine of new grouping lean social sustainability (LSS), lean economic sustainability (LECS), and lean environment sustainability (LENS) to lean sustainability practices (LEAN) according to the discriminant validity output having strong relationship among constructs. The hypothesized model fits the data.

The empirical result suggests that practicing lean sustainability (LEAN) can influence sustainability performance (SP) a direct relationship and supporting Hypothesis 1. The results show a significant and positive association between Lean manufacturing and SP. The β value (β=0.678, P<0.001) in the SEM indicates an exceeding the suggested level (>0.50). The result is consistent with previous researchers of lean and sustainability positive relation as mention in literature review chapter 2. Among three constructs of lean sustainability, lean environment sustainability (LENS) practices result shows the highest effect of factor loading (0.96) the practice and factor loading form three second-order constructs after the final result of the model fit are 1) waste reduction WRN (0.78), 2) High people involvement HPN (0.53), and 3) process center focus PCN (0.51) respectively.

Each of second order construct of WRN, there are four practices 1) Kanban practice reduces waste and scrap, 2) TPM reduce waste and cost, 3) POUS reduce waste of non-value activities, and 4) Continuous flow reduce scrap or backflows. For high people involvement (HPN), there are three practices 1) 5S gain creative input from staff ,2) POUS involve employee, and 3) Continuous flow worker better perform. For process center focus (PCN), there are three practices 1) Kanban cards pull material, 2) Heijunka working together balance fashion, and 3) TPM in continuous improvement target. The next construct of lean sustainability is lean social sustainability (LSS) practices result of factor loading (0.90) the practice and factor loading form three second-order constructs after the final result of the model fit are 1) community contribution CCS (0.70), 2) information transparency ITS (0.63), and 3) work force WFS (0.41) respectively.

Each of second order construct of CCS, there are four practices 1) Clear performance metrics of reputation, 2) Employee participate in community, 3) Charity donations, and 4) Dedicates to local community. For information transparency (ITS), there are three practices 1) Transparency to employee,2) Sustainability audit and public disclosure, and 3) Charitable giving. For work force, there are six practices 1) 5 why engage workers improve workplace, 2) 5 why increase cross-skill, 3) Cross functional team engage employees, 4) Standardized work reduce variations, 5) Standardize work production improve safety, and 6) Visual Management improve safety. The last construct of lean sustainability effect to sustainability performance is lean economic sustainability (LECS) practices result of factor loading (0.85) the practice and factor loading form three second-order constructs after the final result of the model fit are 1) physical productivity PPE (0.83), and 2) product quality PQE (0.81) respectively. Each of second order construct of PPE, there are five practices 1) SPC quality improvement technique, 2) DOE quality improvement technique, 3) Cause and effect or affinity diagram, 4) SMED reduce cost of production, and 5) Existing supplier's approach. For product quality PQE, there are seven practices 1) Monitoring supplier quality improvement, 2) Process management of quality improve, 3) Provide incentives to suppliers, 4) Supplier training to meet economic target, 5) Tracking supplier productivity performance, 6) Establish quality culture, and 7) FMEA quality improvement technique. For sustainability performance, economic sustainability performance (SPEC) shows the most effected from lean sustainability practice with the factor loading (0.98). The items form the final result of the model fit consist of nine performances 1) Increase overall equipment efficiency, 2) Increase R&D budget share, 3) Increase rate of new products, 4) Reduce maintenance hour, 5) Improve percent of suppliers without EHS, 6) Increase the number of customers, 7) Reduce customer complaints, 8) Reduce stops caused by suppliers, and 9) Increase the number of suppliers, respectively.

The following effected from lean sustainability practices to sustainability performance is environment sustainability performance (SPEN) of factor loading (0.83). The items form the final result of the model fit consist of three performances 1) increase amount of recycled, 2) reduce freshwater consumption, 3) reduce energy in production and 4) improve balance of male to female rate, respectively. The last sustainability performance which is affected by lean sustainability practices, is social sustainability performance (SPS) of factor loading (0.59). The items form the final result of the model fit consist of three performances 1) increase level of employee education, 2) increase employee satisfaction rate, and 3) increase support employee health care, respectively.

5.3.3 The developed theoretical model of the influence of lean sustainability practices in sustainability performance of MNCs.

The results show a significant and positive association between lean sustainability practices (LEAN) and Sustainability Performance (SP) which need to combine all three construct to become one latent of LEAN according to the strong relationship among three constructs as explained in chapter 4 as can be seen when comparing two testing between individual three constructs LSS, LECS, LENS effect to sustainability performance by doing this the result of factor loading minus (-15) which opposite with literature of lean social sustainability effect to sustainability performance. In addition, when take into consideration by testing only lean social sustainability (LSS) to sustainability performance (SP) alone the goodness-of-fit of the structural model factor loading shown positive result. From this outcome is reflected to the real situation of the automotive manufacturing firms that they normally implement lean system without considering whether or not cover full scale of sustainability's perspective of triple bottom line. As the original of Lean Manufacturing (LM) has been widely perceived by industry from twenty-first century (Womack, Jones, Roos, & Technology, 1990). The result confirms significant and positive association of lean sustainability which consist of three dimensions according to the research frame work to sustainability performance. The development of model theory the influence of lean sustainability practices in sustainability performance is confirmed by this outcome.

5.4 Research Contribution to answer to research question III: How do the research findings contribute and implicate in the multinational companies (MNCs)?

5.4.1 Current state of lean sustainability practices of Thai automotive manufacturing firms

Thailand, the term "lean" is still limited in the field groups, and sustainability is relatively name familiar but also to perceive the real meaning and value of it still not widely for private sector. However, sustainability issue has a high perceive of the country for SDGs Sustainability Development Goals as of 2019, which Thailand become Thailand is ranked 40th out of 169 countries in the current Sustainable

Development Goals (SDGs) list, making it the highest-ranking ASEAN country. In term of private sector, one of the outstanding areas which lean & sustainability has been implemented and apply is in automotive industry. Thailand Automotive Industry by adopting sustainable manufacturing development for the automotive supply chain, the goal is to establish a comprehensive lean supply chain and green manufacturing system.

In order to justify the benefit of this study, to know the current state of lean sustainability practices of Thai automotive manufacturing firms is important to step up further to improve their actions of lean sustainability practices on the three key dimensions of sustainability: environment, economy, and social (Gimenez et al., 2012, Norman and MacDonald, 2004, Savitz and Weber, 2006).

This study comprises three lean sustainability practices classified by triple bottom line of sustainability, social, economic and environment. The study finding demonstrated a high level of perception to an overall of lean sustainability practice and sustainability performance. The result reflects the prior awareness to specific selection automotive industry to be a field work study as it can be seen as a trend setter for the lean and sustainability context in the country.

5.4.2 In terms of the Manufacturing Sector

Industry has long viewed Lean Manufacturing (LM) as a solution to these problems since it eliminates waste without requiring new resources. The integration of lean and sustainability which now call lean sustainability practices could lead to a direct improvement in their sustainability performance of three aspects social, economic, and environment which the outcomes show that from overall LEAN sustainability, lean environment sustainability practices concern the most effect to economic sustainability performance. The manufacturing can apply this study to implement lean sustainability in their firm which high confident to improve their sustainability performance, for example to emphasis the lean manufacturing of Total preventive maintenance (TPM), Kanban system, point of use storage (POUS), Continuous flow; Heijunka working together balance fashion, and 5S activity which are the practices under lean environment sustainability the most effect to sustainability performance according to the research findings. The result can help the new establishment firm to find the indicator of practices proven the positive outcomes.

5.4.3 The Findings Contributing to the Academic Field

In terms of contribution to the Academic Field, it is valid to mention that it is created a more comprehensive model that lean sustainability effect to sustainability performance. It was one of the studies that investigated the effect of lean manufacturing which develop from literature to generate the lean sustainability practices frame work and investigate their impact of sustainability performance could give the guideline for any sectors interested in studying the relationship them. The next point of this study explored the new measurement scale of lean sustainability and sustainability performance in the context of automotive manufacturing fields in Thailand. Furthermore, it empirically exposes the association of these dimensions with outcomes showed satisfaction and identifies the varying extent of the importance of such dimensions in the relationship. Finally, the study also contributes to the lean sustainability theory by investigating the effect of lean sustainability practices towards sustainability performance in a chosen area of automotive manufacturing where mature development of both lean and sustainability, which was a suitable area of an investigation. The study result provides an innovative model particularly in Thailand industry, which could be the evidence of new contribution for involved sectors.

Lean manufacturing sustainability research is still mostly driven by phenomenological inquiries, rather than theoretical considerations, to examine the link between lean manufacturing techniques and sustainability issues (Dakov et al., 2007, Chiarini, 2014). As a result, the current study's findings benefit not just lean sustainability research, but also other academic areas that were employed to develop the hypotheses under examination. Similarly, various disciplines might have distinct consequences for future study. Two distinct regions are highlighted in the following paragraphs.

The creation of an integrated framework is one of the contributions of this study to lean sustainability research, which identify lean sustainability to three dimensions according to sustainability triple bottom lines addresses the lean sustainability manufacturing according to for the achievement of synergies, each dimension of the lean sustainability variable must be defined. The framework was created based on a thorough assessment of the literature, which allows a new perspective on lean sustainability manufacturing. There was almost no precedent for the inquiry of combine lean and sustainability manufacturing into one success explicitly considered the effect on sustainability performances. In addition, lean manufacturing effect on sustainability performance of early studies considering one part of sustainability performance mostly in lean and green with lack of integration overall triple bottom line of sustainability theory into one research. Directing attention to the total sustainability dimension is the current study's contribution Future lean sustainability studies will need to pay greater attention to this integration than in the past. Furthermore, a number of lean sustainability practices, which have been studied in the past only have a little impact on sustainability performance. However, they have an impact on the performance of other firms or the realization of synergy potential. Other achievement, synergy potential, and synergy realization, which is highly dependent on collaboration between indicators, must be included in order to really comprehend the influence of diverse elements for lean sustainability success methods.

Furthermore, a contribution of this work to lean sustainability research in MNCs context is still very little investigation which in the previous studies were in generic food supply chain, metal-working, shipping and logistic, furniture, cyclic pallet system, supply chain, multisector, general, auto-maker supply chain etc.

5.5 Limitations and Future Research Recommendations

This study can be mentioned is one of the first initiatives to objectively study the influence of lean sustainability techniques on many aspects of companies, with a particular focus on sustainability performance. The following points should be considered in further investigation.

First, current study investigates the lean sustainability practices of firm effect to sustainability performance. Further research can explore firm’s lean sustainability practice implementation level to measure at various levels of lean adoption. Also, longitudinal analysis may be used to investigate the impact of sustainability performance. For instance, the research may evaluate sustainability performance before and after lean social sustainability techniques were implemented. Second, the lean sustainability approaches were picked based on the literature's frequency of areas. Other aspects of lean manufacturing that may have a major impact on sustainability performance must also be examined. Third, apart from lean sustainability practices, future research can consider any other theories in the manufacturing filed that might have significant effect on sustainability performance that need to be considered. Four, depending on the industry area, the scope and focus of lean sustainability techniques adoption varies. Future research might replicate this findings by focusing on a specific environment, such as various industries. Finally, the information was gathered at a particular moment in time. Because this is a cross-sectional study, the data can only reflect the situation at a certain point in time when it comes to lean sustainability strategies. As a result, a long-term examination of lean sustainability practices in a manufacturing business can offer a more accurate picture of the casual link between social, economic, and environmental lean sustainability strategies. Therefore, the overall findings indicate that lean sustainability practices in three dimensions including social, economic and environment were found to have significant effect on sustainability firm’s performance. Future research is urged to utilize this study to investigate the impact of lean sustainability practices on other aspects of a firm's performance, as well as to integrate with other techniques that are best appropriate for the kind of manufacturing business.

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VITA

NAME	Juthamas Brommanop
DATE OF BIRTH	04 August 1972
PLACE OF BIRTH	Pathalung
INSTITUTIONS ATTENDED	The University of The Thai Chamber of Commerce, Thailand Swinburne University of Technology, Australia Stirling University, UK Universite de Perpignan Via Domitia France Silpakorn University International College, Thailand
HOME ADDRESS	69/14/1 Soi Tivanon 18 Tivanon Road Tambon Taladkwan Nontaburi 11000
PUBLICATION	1. Measuring Lean Economic Sustainability: A Scale Development Study Western University Research Journal of Humanities and Social Science 2. Investigating the role of Lean social sustainability on social sustainability performance , Faculty Of Business Administration Rajamangala University of Technology Thanyaburi,Humanities and Social Science Research Promotion Network Journal
AWARD RECEIVED	Awarded of Winner Reach for The Stars 2014,The Recognizing Talent, Acknowledging Outstanding Sales Achievements of Grundfos, Denmark