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A promotional banner for the 240th ECS Meeting. The banner features a colorful striped border at the top. On the left, the ECS logo is displayed in a green circle. To its right, the text reads "240th ECS Meeting" in large blue font, followed by "Oct 10-14, 2021, Orlando, Florida" in a smaller black font. Below this, it says "Register early and save up to 20% on registration costs" in bold black text, and "Early registration deadline Sep 13" in a smaller black font. At the bottom left, there is a red "REGISTER NOW" button. On the right side of the banner, there is a photograph of a diverse group of people in professional attire, smiling and interacting in what appears to be a conference setting.

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A Review of the Combination of Lean and Green in manufacturing for Sustainable Development

A B R Indah¹, Andi Nurwahidah², S Mangngentre¹, N Ikasari¹, and M T Afifudin³

¹Department of Industrial Engineering, Universitas Hasanuddin, Makassar, Indonesia

²Polytechnic ATI of Makassar, Indonesia

³Industrial Engineering, Universitas Pattimura, Ambon, Indonesia

E-mail: a.besseriyani@gmail.com

Abstract. Lean and green are concepts that can not be separated from the business processes of a company, including in manufacturing. A company is easy to achieve but sometimes difficult to maintain it. Maintaining the achievements that have been achieved is a challenge for the company that must be faced. Sustainability is a concept that can help companies maintain their achievements. In this paper we focus on the combination of lean and green in manufacturing to achieve sustainability. Sustainability that is the focus of this paper is based on the triple bottom line, namely economic, environmental and social. Lean implementation is believed to increase the productivity of a company's production system that can improve performance from an economic standpoint. While by applying green the company can achieve productivity in terms of environmental and social aspects. So that by synergizing these two concepts, the triple bottom line can be achieved in accordance with predetermined targets.

1. Introduction

Since last year, several specialized companies in developed countries have faced considerable competition. Big competition is caused by increasing customer demand so every company must deal with it. Lean Manufacturing has been widely adopted. by reducing waste and increasing the value of the production process, making products with more shortcomings, focusing on customers (high quality, low cost, short time), robust production operating systems, and shipping costs are the goals of most companies to face competition [1].

One of the biggest challenges facing manufacturing companies is environmental problems. A growing industry has a major influence on environmental damage. Increasing global warming, effects on human health, ozone depletion, water pollution, biodiversity loss, and economic impacts. Manufacturing systems then evolved by increasing awareness of environmental risks, the need to compete not only efficiently, but migrated from less environmentally friendly to environmentally friendly. An industry can be said to be environmentally friendly if it can minimize or eliminate the presence of environmental waste. Aspects to consider in environmental waste include energy, water, materials, waste, transportation, emissions and biodiversity [2].



In the late eighties, a concept called the concept of sustainable development. The purpose of the mini concept is Development that meets the needs of the present generation without reducing the ability of future generations to meet their own needs. Sustainable companies that contribute to sustainable development by providing economic, social and environmental benefits or what is called a "triple bottom line"[1].

Lean and green are concepts that support the achievement of the bottom line. lean is able to reduce waste in a production process to make the company achieve maximum productivity and increase company profits. Meanwhile, by applying the green principle to the production system, the company releases the waste generated from the production process. by combining these two concepts into the production system, a company can also achieve young development with sustainable development.

Lean focuses on seven forms of waste consisting of overproduction, defects, unnecessary inventory, improper processing, excessive transportation, waiting, and unnecessary movements. while basically environmental waste can also be considered as additional waste. Therefore, the concept of lean and green must be applied simultaneously to reduce waste in the company. Based on this, this paper discusses the integration between lean and green in reducing waste based on lean and waste based on green to reach the triple bottom line.

2. Literature Review

2.1. *Lean in manufacturing*

In terminology Lean is a series of activities or solutions to eliminate waste, reduce non-value added (NVA) operations and increase value added (VA) operations [3]. A lean strategy is a paradigm / concept to produce a repair system that is supported and eliminates all forms of waste from production and supply chains to improve quality, reduce costs and increase value for customers[4]. Lean can be identified as a systemic and systematic approach to identifying and eliminating waste, or non-value-adding activities through continuous improvement by flowing products (material, work- in process, output) and information using internal and external pull systems to pursue excellence and perfection [5]. Lean which is applied to the whole company is called Lean Enterprise. Lean which is applied in manufacturing is called Lean Manufacturing. There are five basic principles of Lean [2].

1. Identifying product value based on customer perspective
2. Identify Value Stream Mapping for each product.
3. Remove waste that does not add value from all activities along the value stream.
4. Organizing so that material, information and products flow smoothly and efficiently throughout the value stream process using a pull system
5. Continue to look for techniques and tools for improvement (improvement tools and techniques) to achieve excellence and continuous improvement.

LEAN MANUFACTURING

Lean Thinking

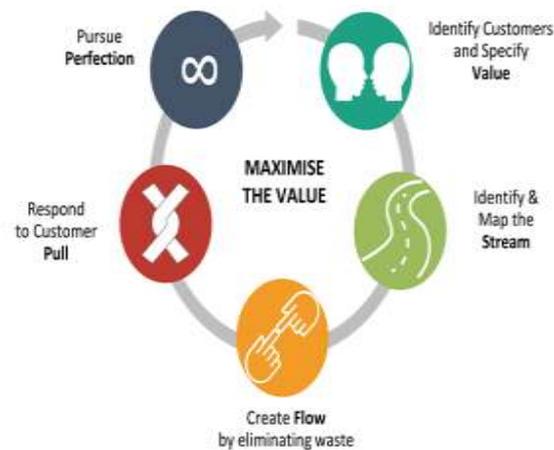


Figure 1. Principles of Lean

Lean manufacturing is a systematic approach to identifying and eliminating waste through continuous improvement, in order to create a smooth production process flow with fast lead times and little waste[6]. lean manufacturing is a production system that uses very little energy and waste to fulfill what consumers want precisely. The purpose of lean manufacturing is to eliminate waste (non value adding activity) from a process so that activities along the value stream are able to produce value adding[7]. in the Toyota Production System (TPS) there are seven waste in the production process, namely as follows [8]:

1. Overproduction, which is a waste caused by excessive production, the intention is to produce products that exceed what is needed or produce earlier than the schedule that has been created.
2. Waiting, which is a waste of time waiting for the next process. Waiting is an interval when the operator does not use the time to do value adding activity because it waits for the product flow from the previous process (upstream).
3. Transportation, transportation is an important activity but does not add value to a product. Transportation is the process of moving material or work in process (WIP) from one work station to another, using either a forklift or conveyor
4. Excess processing, occurs when work methods or work sequences (processes) used are deemed unfavorable and flexible.
5. Inventories, are inventories that are less necessary. The point is that there is too much material inventory, too much work in process between one process and another that requires a lot of space to store it, the possibility of this waste is a very high buffer.
6. Motion, is an unnecessary activity / movement carried out by the operator that does not add value and slow down the process so that the lead time is long.
7. Defects, are products that are damaged or not according to specifications. This will cause an ineffective rework process, high customer complaints, and very high level inspection.

2.2. Green in Manufacturing

Green is a concept that deals with supply chains and production in the environment and handling in the environment consisting of air, energy, air, solid and hazardous waste [4]. Green Manufacturing aims to

continue the integration of industrial processes and products, to reduce or avoid pollution in air, water and soil, to reduce waste at its source and to minimize risks to humans and other species[9][2]. Green Manufacturing includes several practices namely pollution prevention and reduction of toxic use and design for the environment. Pollution prevention focuses on avoiding or minimizing waste or emissions through source reduction or on-site recycling. Reducing resources can be achieved in various ways that relate well to the process and the product [10][2].

1. Product Modification, when the composition of the shape and material of the product changes.
2. Input substitution, which means raw materials and non-polluting additives are used as process aids (for example lubricants and lubricants) with longer service time.
3. Modification of technology includes improving the automation process, process optimization, redesign of equipment and substitution processes.
4. Good Housekeeping, means changes in operational and management procedures to reduce or eliminate waste and emissions. For example spill prevention, increase worker instruction and training.

2.3. Comparison of Lean and Green Manufacturing

There are five steps in Lean Manufacturing, namely defining the flow of customers, defining the flow of value, making it "flow", "pulling" from customers, and striving for excellence [11]. In the first step, the customer's value must be determined, because you have to know what the customer wants and what the customer does not want from the production. However, customers can be interpreted in different ways, so there must be different types of waste, as shown in Figure 2.

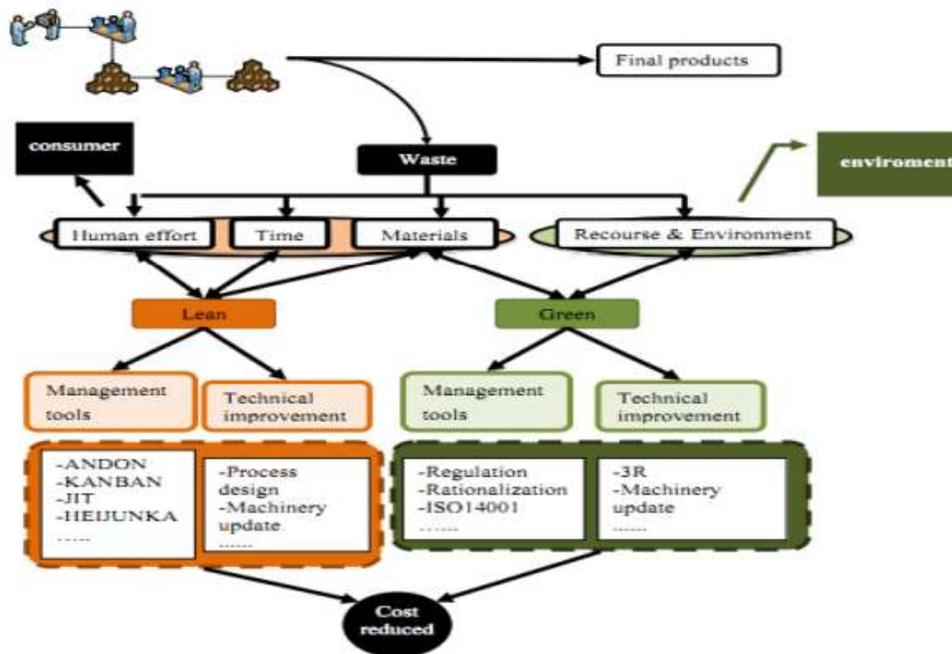


Figure 2. Lean waste and environmental waste are seen from a perspective Different

Some people argue that being environmentally friendly will incur costs, but being environmentally friendly means also saving costs from disposition of waste, emissions and exemption from collecting fines due to pollution, as well as the use of recycled materials. There will be a break even point between costs and benefits of being environmentally friendly. For those who have limited financial capacity, they can try to find a break-even point and plan investments that are appropriate for the company's sustainability [2].

2.4. Lean and Green for Sustainable Development in Manufacturing

Sustainable Manufacturing itself is defined as "the creation of products of economic value through processes that minimize negative impacts on the environment, save energy and natural resources, and conserve natural resources and energy to guarantee their availability in the future. The process must also be safe for employees, the public, and consumers." Sustainable Manufacturing "is an evolution of manufacturing systems ranging from traditional manufacturing systems, then lean manufacturing that focuses on reducing waste (waste reduction based), green manufacturing with 3R, until finally on the concept of sustainable manufacturing with the 6R approach to the product life cycle [12]. The implementation of Sustainable Manufacturing leads to the achievement of (sustainable development) as stated by the World Commission on Environment and Development is defined as "development that meets current needs without compromising the ability of future generations to meet their own needs" [13]. Tripple bottom line is the company's sustainability and growth does not depend on operating profit, but also concrete actions taken by the company on the environment, and justice. and everything is done in order to create sustainable development [14].



Figure 3. Manufacturing in relation to the three pillars of sustainability

The concept of sustainability can be broken down into three aspects of understanding, namely [15]:

1. Economic sustainability, which is defined as development able to produce goods and services continuously to maintain the sustainability of government and avoid it happening sectoral imbalances that can damage agricultural production and industry.
2. Environmental sustainability: An environmentally sustainable system must be able to maintain stable resources, avoid the exploitation of natural resources and the function of environmental absorption. This concept also concerns the maintenance of biodiversity, stability of airspace, and other ecosystem functions that are not categorized as economic resources.
3. Social sustainability: Social sustainability is defined as a system capable of achieving equality, providing social services including health, education, gender, and political accountability

3. Implementation of Lean and Green for Sustainable Development

The interesting thing when discussing green manufacturing is how to distinguish green from lean manufacturing. The two terms are sometimes used interchangeably even though they actually have different end goals. Lean and green practices are complementary. Lean manufacturing focuses on how to create greater value for consumers with less work [12]. Researches that discuss green and lean manufacturing include research on the concepts of green and lean manufacturing [16]. in [17] explained about green manufacturing, why green manufacturing is needed and green manufacturing methods to reduce waste and pollution. As stated in [18] There are 8 frameworks with different names used for the assessment of green aspects. Most frameworks use the product life cycle and study the system to request implementation. while [19] makes discussions about lean and green articles covering compatibility; integration with Six sigma, resilience, agile, global supply chain; integration of lean and green; application (empirical) in several industrial sectors and management functions; and its effect on performance. As for research on the relationship between green and lean, Green Practice is in line with the concept of Sustainable (sustainability). Both concepts must be brought together at the level of development, implementation, and education [16]. Other than that research about lean practices and green manufacturing influence each other. There are three types of lean and green manufacturing relationships, namely Lean and green manufacturing complement each other, Synergy between the two concepts results in better performance; and Reciprocal relationship between lean and reduction of environmental waste [20]. As for research on green and lean for sustainable which [4] explains about addressing sustainability performance or the triple bottom line to manage organizations and their supply chains with the aim of improving the performance of green and lean-based organizations. In [21], a systematic review was conducted on Manufacturing SMEs which took the initiative to implement green and lean to achieve sustainable development.

4. Conclusions and Future Work

As for the conclusion in this paper that green is a concept that has been developed by several companies by focusing on waste that can pollute. while lean is a concept used to achieve maximum productivity in a production system. by integrating these two concepts, a company can easily achieve sustainable development based on a triple bottom line consisting of economic, environmental, and social. by implementing lean and green continuously, a company is able to maintain its achievements in the economic, environmental and social fields that can be achieved in a sustainable manner. In future research may be done after the performance assessment applied lean and green is based on the triple bottom line by using the systematic method. As for the variables that can be assessed, namely the achievement of performance in terms of economic, environmental, and social.

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