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LEAN-GREEN MANUFACTURING TO SUSTAIN ENVIRONMENTALLY FRIENDLY INDUSTRY: A REVIEW

Abstract: The increase in greenhouse gas emissions has worsened the global warming condition in the world day by day. One of the biggest contributors to greenhouse gas emissions is the manufacturing industry. Carbon dioxide is produced as a byproduct of the manufacturing industry. To reduce greenhouse gas emissions, it is important for the company to focus on how to manage waste in non-value-added operations. This study reviewed the literature on the integration of Lean and Green Manufacturing to sustain an environmentally friendly and efficient process. A total of 24 out of 107 papers were reviewed in this study. The implementation, differences, similarities, synergies, advantages, impacts, and barriers of Lean and Green Manufacturing were used as inclusion criteria. The findings of this study showed that Lean and Green Manufacturing integration can eliminate operational and environmental waste effectively, which in the end will increase productivity while reducing global warming impact.

Keywords: Gas emissions, Global warming, Greenhouse, Lean-green manufacturing, Waste.

1. INTRODUCTION

Greenhouse gas emissions worsened the global warming condition in the world. The biggest contributors to greenhouse gas emissions are energy consumption, agriculture, and the manufacturing industry (Ge & Friedrich, 2020). Greenhouse gas emissions will continue to happen and worsen the global warming condition if the players in the manufacturing industry do not take any action to reduce the byproduct of the industry. This might happen because of a lack of awareness from the companies regarding the issue. Even when the companies already are aware of greenhouse gas emissions and try to sustain the environment, they might not know how to reduce the emissions. Many of the manufacturing processes are inefficient and contribute a large portion to greenhouse gas emissions (Lamb et al., 2021).

Adapting green manufacturing processes to manufacturing operations could reduce the emissions released into the atmosphere (Singh et al., 2022). However, implementing green manufacturing itself is not enough since this method will only reduce waste during the production process (Pathak et al., 2021). If we take a look at the manufacturing process closer, we will find that waste could happen even outside of the production process, which is called non-value-added activities. Non-value-added activities are all activities consuming time or cost but will not give any profit to the company, i.e., unnecessary movement of materials and unnecessary movement of employees. To reduce or even eliminate waste from non-value-added activities, lean manufacturing can be adapted to the operations of the manufacturing industry.

The purpose of integrating lean manufacturing and green manufacturing is to get the full advantage of eliminating waste in the manufacturing process. The integration of lean and green manufacturing not only will increase the performance of the company but also sustain the environment (Hallam & Contreras, 2016a). The aim of this study is to review past literature related to lean and green manufacturing integration in eliminating waste (Garza-Reyes, 2015; Cherrafi et al., 2016; Tiwari & Tiwari, 2016; Siegel et al., 2019; Leong et al., 2019) and increasing value-added (Cherrafi et al., 2016; Hallam & Contreras, 2016a; Tiwari & Tiwar, 2016; Abreu et al., 2017; Inman & Green, 2018). In addition, this study also provides suggestions for future research on lean-green manufacturing based on the findings of the review.

2. METHODS

This study reviewed the impact of the application of lean-green manufacturing on environmental sustainability. The reviewed articles were obtained from the research databases such as Scopus, Web of Science, JSTOR, ERIC, ScienceDirect, and IEEE Xplore. The keywords used to obtain the articles were "Lean and Green Manufacturing", "Integration of Lean-Green Manufacturing", "Lean-Green Manufacturing", and "Application of Lean-Green Manufacturing". Then the collected articles were screened based on the title, abstract, and year of publication. The limitation for the year of publication was set from 2015 to 2022. A total of 107 articles were collected and there were 56 articles found to be relevant to the inclusion criteria. The implementation, differences, similarities, synergies, advantages, impacts, and barriers of Lean and Green Manufacturing were used as inclusion criteria. There were 21 out of 56 articles that specifically discussed the integration of lean and green manufacturing.

3. RESULTS AND DISCUSSION

3.1. Lean-Green Manufacturing

Lean and green manufacturing integration is a way to improve the production process while sustaining the environment. Lean manufacturing was developed by Toyota to eliminate seven wastes in the production process. The seven wastes to be eliminated are defective products, over-processing, waiting time, overproduction, inventory, transportation, and unnecessary movement. Whereas green manufacturing is used to eliminate green wastes such as the consumption of energy, water, and resources (Chiet et al., 2019) to sustain the environment. Integrating the concepts of lean and green manufacturing can maximize waste elimination and increase the efficiency of the production process (Bhasin, 2015). Lean and green manufacturing basically have the same purpose, which is enhancing product quality while reducing operational costs (Hallam & Contreras, 2016a). In addition, both lean and green manufacturing are aiming to produce zero-defect products (Tiwari & Tiwari, 2016).

The common goals between lean and green manufacturing make them possible to be integrated since they can work synchronously to increase efficiency and effectiveness in the manufacturing process (Tiwari and Tiwari, 2016). Further, lean-green manufacturing is an effective method to improve performance while reducing production costs by eliminating waste and non-value-added activities (Garza-Reyes, 2015). Lean-green manufacturing can achieve a sustainable manufacturing system due to its four dimensions, namely, quality, delivery, cost, and environment with a focus on eliminating waste and increasing performance (Pampanelli et al., 2015; Abualfaraa, 2020).

3.2. Lean-Green Manufacturing to Increase Value-Added

Lean and green manufacturing are integrated by manufacturing companies to increase value-added in the production processes. The increase in value-added can be achieved by reducing production costs and time, minimizing waste, and improving the quality and efficiency of the process. If the company is able to implement lean-green manufacturing consistently, an increase in the value-added process along with a decrease in production costs can be obtained (Hallam & Contreras, 2016b). From its initial purpose, green manufacturing intents to eliminate waste to the environment by minimizing the usage of natural resources. In addition, green manufacturing also aims for zero-defect products (Tiwari & Tiwari, 2016). Similarly, lean manufacturing is used to eliminate the seven wastes to improve the performance of the production process (Inman & Green, 2018). The implementation of lean manufacturing in companies with a green manufacturing approach could sustainably minimize overproduction, unnecessary movement, and waiting time that in the end will increase the value-added processes (Cherrafi et al., 2016).

Lean-green manufacturing can also be applied to supply chain management in order to reduce operational and environmental wastes which will result in better competitiveness in the global market (Abren et al., 2017). Lean-green manufacturing could minimize the total cost and increase the efficiency of the supply chain processes from the raw materials until the products reach the customers. Additionally, lean-green manufacturing could reduce the lead time of the processes, improve the culture of the organization, and improve the social position of the company (Abren et al., 2017). This is because lean-green manufacturing will reduce the cost of production and inventory, shorten the production cycle and lead time, reduce the delivery time, and improve the safety of the employees.

3.3. Lean-Green Manufacturing to Sustain the Environment

The integration of lean and green manufacturing also aims to minimize waste to the environment. Japan implemented lean-green manufacturing by developing machines with low-carbon emissions (Leong et al., 2019). These machines are able to reduce greenhouse gas emissions in Japan and also reduce the total production costs. The implementation of lean-green manufacturing will be able to minimize the global warming condition that is harmful to the environment and natural resources (Garza-Reyes, 2015; Cherrafi et al., 2016). Lean-green manufacturing has been proven to minimize any kind of production waste efficiently (Tiwari & Tiwari, 2016). Not only beneficial to the environment and production process,

but the employees will also get the benefit of a better and healthy working environment. A healthy and safe working environment itself could be obtained by improving employee awareness, training, and standardized assessment (Siegel et al., 2019).

3.4. Barriers to Implement Lean-Green Manufacturing

Despite its advantages, lean-green manufacturing may not be able to be implemented easily. This is because there are barriers that make the implementation more difficult. The implementation of lean-green manufacturing requires a large amount of financial investment with no guarantee it will be successful (Chiet et al, 2019). Not only financial barriers but the implementation of lean-green manufacturing might also be restricted by the capability of the stakeholder and the company. When the involved employees are not capable enough, it will be difficult to effectively lean-green manufacturing (Leon et al., 2019). Similarly, it will also be difficult when the company is not ready for the change using lean-green manufacturing concepts (Abren et al., 2017). Other than the internal factors from the company, external factors can also be a barrier to lean-green manufacturing implementation. Lean-green manufacturing will not achieve sustainability by itself due to contingency factors such as organizational culture, financial capability, employee involvement, leadership commitment, and suitable organizational structure (Bhattacharya et al., 2019). The next barrier is the behavior of lean-green manufacturing that may not be able to support the sustainability pillars, namely, environment, social, and economy (Abualfaraa et al., 2019). Thus, another method is required to achieve the sustainability pillars.

3.5. Lean-Green Manufacturing Implementation

The company must be able to put more attention to the barriers to lean-green manufacturing implementation to determine the root causes of the barriers. It is important to identify the root causes of the barriers in order to come up with strategies to overcome the obstacles. If the obstacles can be tackled, the advantages of lean-green manufacturing in increasing value-added and sustaining the environment can be obtained. In addition, it is important to use a suitable performance measurement system to check the successfulness of the implementation of lean-green manufacturing. The performance measurement should be designed based on the company's condition because the successful implementation in one company is not a guarantee that it will be successful in all companies. If the company does not use the proper performance measurement, it is going to be difficult to measure the performance of lean-green manufacturing in increasing value-added and sustaining the environment. A generic measurement cannot be used to judge the performance of lean-green manufacturing in a company since even the same businesses may have different processes. Poor understanding of how the production system and how to measure the performance of lean-green manufacturing is one of the causes of the failure in the implementation of lean-green manufacturing. According to Abualfaraa et al. (2020), the proper method and parameters to evaluate the success of the implementation of lean-green manufacturing are still lacking. Future studies developing a suitable method and parameters to measure the performance of lean-green manufacturing based on the company's specific operation would support the success of implementing lean-green manufacturing.

4. CONCLUSION

From the articles reviewed, it can be concluded that implementing lean-green manufacturing increased value-added in the production process and brought a positive impact on environmental sustainability. Lean manufacturing complements green manufacturing to reduce not only operational waste but also environmental waste effectively. Further, lean-green manufacturing could minimize the total production cost and increase the efficiency of the production process. Although the integration of lean and green manufacturing brings a lot of advantages, it is not that simple to implement this method. The company needs to have good preparation such as a large amount of financial investment, organizational readiness, advanced technology, and the involvement of capable employees. Otherwise, there is no guarantee the implementation of lean-green manufacturing will be successful. In addition to that, it is also important to have a proper measurement method to evaluate the performance of lean-green manufacturing. This study provides evidence from the literature review that lean-green manufacturing could give a positive impact on the production process while sustaining the environment. This study also presents the possible barrier to the implementation of lean-green manufacturing along with how to overcome it. Future research evaluating lean-green manufacturing should focus on the specific industry since each industry has its own characteristics.

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