INNOVATION LEAN PRINCIPLES IN AUTOMOTIVE GREEN MANUFACTURING

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Abstract: Today, industries such as automotive and manufacturing industries deal with a lot of environmental regulations. Lean is a production strategy whose fundamental principles drive the industry towards a more effective production of goods and services. The eco-efficiency concept is primary to sustainable development and intends to provide more value with less environmental impact. The aim of this study is to identify and explore the contributions of Lean to reduce environmental impacts that naturally result from industrial activity.

1 Lean Manufacturing System

Lean manufacturing is a efficiency based system on optimizing flow to minimizing the wastage and using advance methods to improve manufacturing system by modified or change pre-existing ideas [3].

Another definition say that Lean Manufacturing is a philosophy that aims to maintain smooth production flow by continuously identifying and eliminating waste resulting in increasing value of activities in the production process. Lean manufacturing approach makes an organization able to sustain market competition by improving its competence for better quality; on time delivery with lower cost Lean Manufacturing aims for Identification and elimination of waste (any activity that does not add value to customer) [1].

Lean manufacturing aims to continuous flow of all manufacturing processes with minimum as minimum wastage. The whole process must be free from waiting, disruption, and backflow.

The basic Elements of Lean Manufacturing System is [6]:

- KANBAN
- TPM (Total Productive Maintenance)
- JIT (Just In Time)
- KAIZEN (Change For Better)
- Quality Circles
- TQM (Total Quality Management)
- Employee Involvement
- 5's

Main benefits of Lean Manufacturing System is [6]:

- Improve productivity
- Overall wastage reduction
- Cost reduction
- Reduce defects
- Overall quality improvement

2 Principles of Green Manufacturing

According to Balan (2008), Green manufacturing is an approach, that all innovative techniques towards effective environmental solutions that result in cost savings from reduced work handling, effluent control, and process automation or other environmental and operational benefits [5]. Faster and cheaper are no longer the only two success measures of manufacturing a product or evaluating an existing process line but also other success factors such as materials used in manufacturing, generation of waste, effluents and their treatment method, life of the product and finally, treatment of the product after its useful life are important elements that added by green manufacturing approach as success factors [4], [5].

The issues that green manufacturing is mostly addressing in process level, and accordingly the objectives of green manufacturing can be stated as the following [10]:

- Provide a cleaner source of energy through new technology or approaches.
- Decrease energy consumption in processes by implementing new technology or approaches.
- Convert pollutants and wastes into byproducts and promote their use and recycling along with that of the product in order to reclaim the energy expended in the process and conserve resources.
- Maximize yield and minimize waste effluents via process improvements, such as by tailoring feedstock selection, selecting proper fuel mix, automation, and establishing control strategies via sensors with real-time feedback loops that control process parameters.

Following Table 1 summarizes similarities and differences between the two concepts - Lean and Green [2].

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Table 1: Lean and Green manufacturing concepts comparison

Aspect	Lean manufacturing	Green manufacturing
Focus of the concept	Focuses on enhancing competitiveness through value creation for customers. Quality, waste minimization/elimination and delivery times are key issues.	Focuses on integration of environmental improvements of industrial processes and products. Reduction or prevention of pollution to air, water and land; reduction of waste at source; and minimization of risks to humans and other species are key issues
Basic principles of the concept	Includes a number of principles related to four categories: philosophy (long-term thinking), process (elimination of waste), people and partners (respect, challenge and grow them), and problems solving (continuous improvement and learning)	Includes principles related primarily to three categories: pollution prevention, reduction of use of toxic substances, and design for environment.
Product and/or process focus	Mainly focus on processes, but the products' influence on performance of processes is strongly acknowledged. Lean product development is a complementary view on the lean enterprise	Focus on both processes and products.
Methods/tools	Various tools are used for process improvements	Various tools are used for improvements of environmental performance of processes and products
Employee involvement	Involvement of employees is key in order to achieve continuous improvement and learning.	Involvement of employees is key in order to implement measures for improving environmental performance of both processes and products
Supply chain involvement	Customer focus and involvement as well as close cooperation with suppliers are important	Involvement of suppliers is essential because sharing and integration of ideas for environmental improvements across organizational boundaries will support the achievement of high environmental performance in manufacturing

3 Lean Impact on Enviromental Performance of Production Systems

Some automotive companies such as Toyota define their new production philosophies as a combination of lean and green approach in order to cope with market and society's heavy environmental requirements.

According to many case studies from praxis, it could be concluded that Lean management has a positive impact on environmental performance of production systems. This is particularly truth for continuous improvement culture and waste reduction. Figure 1 illustrates, by way of a cause-effect diagram (Ishikawa diagram), the origins and implications of waste within production systems [2].

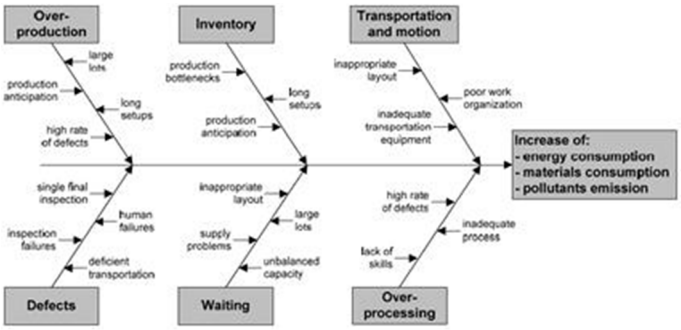

Figure 1: Production wastes of weak environmental performance

This diagram (Figure 1) includes the main causes of each type of waste providing thus valuable hints on how to reduce them. For example, the reduction of equipments' setup time (by applying the SMED methodology – Single Minute Exchange of Die) contributes to reduce both overproduction and inventory. These reductions naturally lower the energy and materials consumption while reducing the emissions. Figure 2 show the main effects of each production waste. All the consequences resulted from the 6 waste types, illustrated in figure 2, can be detailed within the previous classes of environmental impact, namely: energy use, materials consumption and emissions (Figure 1).

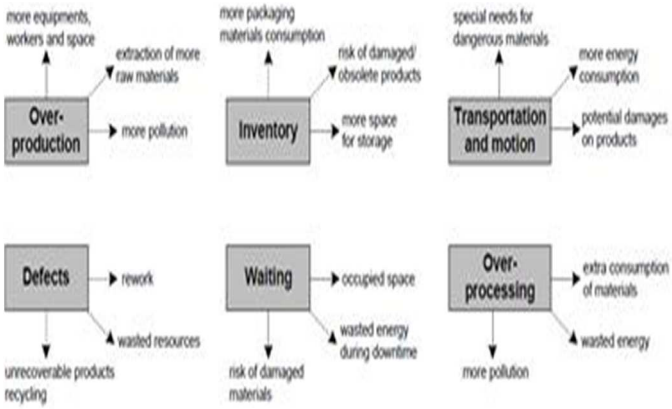

Figure 2: Effect of production wastes [2]

4 Tools and Implications for Enviromental Performance and Benefits

Lean tools can have a lot of implications to environmental waste in general. EPA's lean tools based researches conducted in organizations from various industries has provided an extensive knowledge regarding 5S, TPM, Cellular Manufacturing, JIT/Kanban, Kaizen Events, Six Sigma and their implications for environmental performance and benefits in waste reduction sense. In this chapter is sumarized list of summarizes lean tools and their implications for environmental performance and benefits from a broad environmental waste aspect including implications for chemicals and energy use [3], [7].

5S Method:

- Energy needs can be decreased under the Shine pillar when equipment is painted light colors and surroundings are cleaned.
- Enables workers to be aware of spills or leaks promptly in such workplace so that it makes less waste generation from spills and clean-up.
- Clearly-marked and obstacle-free thoroughfares can reduce potential for accidents of spills and associated

hazardous waste generation (e.g., spilled material, absorbent pads and clean up materials).
- Cleaning regularly, in case cuttings, shavings, dirt, and other substances are accumulated as well as contaminate production processes which can result in defects, can reduce energy and resources needs and avoid waste.
- Organizing and disposing of unused equipment and supplies, which can reduce floor space needed for operations, is benefit for environment because it can save heat and light.
- EPA has proved that organizing equipment, parts, and materials and making them easy find can reduce unneeded consumption because workers prefer to finish one batch of materials or chemicals before opening or ordering more when things are in good order.
- 5S visual cues (e.g., signs, placards, scoreboards, laminated procedures in workstations) can improve employee environmental management as well as increasing their awareness of waste handling and management procedures, workplace hazards and emergency response procedures [8], [9], [12].

TPM (Total Production Maintenance)
- Appropriate equipment and systems maintenance makes fewer defects from a process. Defects reduction can conversely help eliminate waste from processes in fundamental ways.
- TPM can prolong using-life of equipment. Hence, pressure is released for purchasing and/or making replacement equipment. In the other hand, it can also reduce the environmental impacts caused in processes to produce new equipment.
- TPM program may also decrease the solid and hazardous wastes associated with the number and severity of spills and leaks, upset conditions [10], [11], [12].

JIT/KANBAN
- Overproduction can be eliminated by the tool of JIT/Kanban. JIT/Kanban can also reduce waste and the use of energy and raw materials by elimination overproduction.
- JIT/Kanban systems can be applied to reduce inventory both in-process and post-process, which can help to avoid potential wastes caused by product handling [12], [13].

KAIZEN
- The core of Kaizen is to eliminate waste from a targeted process. The typical outcomes of Kaizen culture and process have many similarities to those required by environmental management systems, ISO 14001, and pollution prevention programs. Kaizen involves all workers who may play a critical part in a certain process as well as encourages them to take part in waste reduction activities. Suggestions or opinions on process improving and waste reduction are usually from employees who work in a particular process.

Six Sigma
- Six Sigma can reduce defects by removing variation from production processes. This, in turn, can help to remove waste from processes in three key ways: 1.Decrease the number of products that must be scrapped; 2.Reduce the raw materials, energy and resulting waste resulting from the scrap; 3.Decrease the amount of energy, raw material, and wastes caused by fixing defective products that need to be re-worked.
- Six Sigma tool can free workers to focus more on improving conditions that can cause accidents, spills, and equip mental functions. This can also help to achieve reduction of solid and hazardous wastes associated with spills, leaks, and their clean-up.
- Six sigma can extend product lifetime by increasing durability and reliability of product, in the other words, it can reduce the frequency to replace products, as well as decrease the environmental impacts resulting from meeting customer needs [12], [14], [15].

Sustainable and Lean construction tools enable project cost reduction and accelerated implementation.
- Safety plans
- Site recycle and waste management program
- Commissioning plan
- Lean construction scheduling process
- Lean supply and Lean assembly

Main Lean and sustainable lifecycle operations can be summarized as:
- Lean Sustainability Enterprise framework
- Performance tracking
- Operational efficiency and eco-efficiency
- Training and knowledge transfer
- Project selection, project implementation
- Mentoring and coaching of the organization for continuous improvement, change management and lasting results.

Lean and Sustainability principles are also applicable to the last stages of the facility life cycle. Cost-effective and sustainable decommissioning can be achieved by:
- Planning for decontamination and decommissioning
- Equipment refurbishing, relocation & reuse
- Sustainable building reuse or building demolition
- Recycling of materials collected during decommissioning
- Assistance site sale or lease

Green manufacturing also relies on several methods/tools. The methods/tools relates to both processes and products. In general, the methods/tools can

be classified as assessment oriented or improvement oriented. The perhaps most well-known method/tool is the Life Cycle Assessment (LCA). It aims at analyzing environmental impacts over the entire life cycle (raw material extraction, material production, manufacturing, use, and end-of-life treatment) of a product (or service). Various improvement tools have also emerged, such as different DfE handbooks for various types of products, lists of restricted or banned substances, etc. Hence, both Lean and Green manufacturing rely on the application of various types of methods/tools [6], [16], [17] , [18].

Conclusion

Lean and Eco-efficient production systems are highly positive in their findings, resulting in strong evidence that Lean has in fact a positive contribution in the improvement of the environmental performance.

Green concept asserts reduction of material waste and emissions, fewer production steps which also support high resource productivity. Furthermore, the strong focus on continuous improvement in the Lean concept needs employee involvement and training. Improvements of environmental performance, as advocated by the Green concept, also require employee involvement and training. Both concepts require changed mindsets and establishment of company cultures supporting the philosophy underlying each concept. Another feature of the Lean concept is not only to solve any problem that occurs in manufacturing, but to avoid occurrence in the future. This displays similarities with the Green manufacturing concept, which advocates source reduction. That is, attention should be paid to avoidance of negative environmental impacts rather than use of "end-of-pipe" solutions when the impacts occur.

While the depth and variety of these manufacturers' investments are indicative of the automotive industry's movement towards greater use of renewable energy sources and "greening" manufacturing processes, there is still a tremendous amount of untapped potential, both for the industry, and for the nation as a whole. To realize this potential, companies need to take a holistic approach to updating their facilities and define a comprehensive sustainability strategy that is scalable, replicable, and economically viable. Simply "greenwashing" a facility is not sustainable; the automotive industry needs to focus on the environmental impact of its decisions as well as the operational and economic impact of its investments in clean technologies.

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