

# Studies Linking Lean Manufacturing Methodology with Green Manufacturing

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**Abstract:** Lean manufacturing means manufacturing without waste. Anything else which are not adding any value to the product are considered as waste as per lean concept. Inventories of raw materials, work in process inventories, inventories of finished product, overproduction, waiting of equipment ,waiting of human resources, space occupied by unused equipment and materials, excess used of materials etc. are the waste as per lean concept. Green manufacturing means manufacturing means manufacturing without pollution and optimum use of natural resources. Hence if lean manufacturing concept are adopted by any industry, they automatically moves towards green manufacturing also and vice versa. Thus it is said that manufacturers can be green and highly profitable at the same time. Profits do not have to be sacrificed to environmental responsibility, or vice versa. The two strategies (lean and green) can be integrated and offered simultaneously that will reduce environmental pollution, optimum utilisation of resources and improvement in productivity.

## 1. INTRODUCTION

The aim of lean manufacturing is to eliminate waste from the systems and operations and extracting as much outputs as they can from minimal inputs. Waste is anything other than the minimum amount of equipment, materials, parts, and working time, which absolutely are vital to production (Taj & Morosan, 2011).

Green Manufacturing is a method of manufacturing that minimizes waste and pollution. Green Manufacturing goals are also to use minimum natural resources and conserve it for future generations. The benefit of Green Manufacturing is to create a great reputation to the public, saves useless cost, and promotes research and redesign. Thus, green manufacturing refers to how goods and services are produced with limited effects on the environment under present technological and economic challenges (Oliveira et al., 2008).

Recent studies suggest that lean manufacturing may be integrated with green manufacturing to get the benefit of both waste reduction and pollution reduction. The purpose of the research is to illustrate scope of the integration of lean and green manufacturing so as to eliminate waste and to incorporate environmental protection into business performance.

## 2. LITERATURE REVIEW AND SYSTEM MODELS

For comparative purposes this section discuss the relevant literature on lean and green manufacturing and its integration. For system models development for Lean manufacturing, Green manufacturing and Combined Lean & Green manufacturing, same three main categories are: Manufacturing Waste, Waste Reduction Techniques and its Business Outcome. The literatures review with system models have been presented in the following sequences:

- (a) Literature review of the Lean manufacturing and its System model
- (b) Literature review Green manufacturing (GM) and its system models
- (c) Literature linking lean manufacturing methodology with green manufacturing and its comprehensive system models.

### 2.1 Literature review of the Lean Manufacturing and its System Models

The goal of lean manufacturing is to reduce waste. Russell and Taylor (1999) define waste as anything other than the minimum amount of equipment, effort, materials, parts, space and time that is essential to add value to the product. Agha et al. (2010) deals with quantifying the effects of implementing lean construction using discrete system simulation.

Table 1: Shows the lean manufacturing system models

**Table 1: Lean Manufacturing System Models**

Lean Manufacturing Waste	Lean Waste Reduction Tools and Technique	Lean Business Outcome
Overproduction	5 S	Improve Quality
Inventory of Raw Materials	3 R / 5R	Reduce Cost
Work in Process Inventory(WIP)	Value Stream Mapping(VSM)	Right Time Delivery
Inventory of Finished Product	Kanban	Customer Satisfaction
Waiting of Equipment	Kaizen	Increase Profitability
Waiting of People	Pokayoke	Improve Productivity
Unnecessary Movement of Materials	SMED (Single Minute Exchange of Dies)	Reduce Lead Time
Unnecessary Movement of Finished Product	Takt Time	
Unnecessary Movement of Equipment	Just in Time	
High Rework or Defects	Operator Care program	
Excessive scrap	ISO 9000	
High rejection	Total Productivity Maintenance(TPM)	
Frequent warranty claim	Total Quality Management(TQM)	
Lost people potential or Unused creativity		
Poor Plant Layout		

**2.2 Literature review of Green Manufacturing and its System Models**

The level of CO<sub>2</sub> emissions that are imposed on developing countries and especially on India and China, two of the world’s fastest growing economies, creates the necessity of shifting the concentration towards environment friendly ways of production and manufacturing. This also makes us to think towards the sustainable development (UN Report, 2010). Deif (2011) presents the model which can capture various planning activities to migrate from a less green for the new green manufacturing paradigm into a greener and more eco-efficient manufacturing. Fore et al. (2010) suggested green manufacturing in foundry. According to Rahma et al. (2009) cleaner production (CP) can reduce cost, based on competitive advantage and environmental aspect approaches. The

approach towards the CP practices is to: reduce, reuse, recycle, and reproduce and recovery (i.e., 5R). Selinger et al. (2008) identify a research and development plan for sustainable manufacturing focusing on enhancing use-productivity. Hosseini (2007) discusses the basic factors and a conceptual model in the adoption and maintenance of green management system. It is anticipated that if organizations ensure these factors, they will experience less resistance from their stakeholders and consequently they will have a successful GM (green management) and GP (green productivity) implementation. Huiy et al. (2002) presents a case study demonstrates that the fuzzy set-based model can effectively account for the vagueness and uncertainty of information being used for environmental impact of a manufacturing process. Table 2 shows green manufacturing system models.

**Table 2: Green Manufacturing System Models**

Green Manufacturing Waste	Green Waste Reduction Technique	Green Business Outcome
Pollution of the Environment	Product Redesign	Reduce Pollution
Air Pollution	Process Redesign	Reduce Materials Consumption
Water Pollution	Reduce	Reduce Cost
Optimum Utilization of Natural Resources	Reuse	Increased Productivity
	Recycle	Increased Profitability
	Reproduce	
	Recovery	
	Remanufacturing	
	Waste Segregation	
	ISO 14000	

**2.3 Literature linking lean manufacturing methodology with green manufacturing and Comprehensive Lean and Green System Models**

As per the book of Hillis et al. (2012) Manufacturers can be green and highly profitable at the same time. Profits do not have to be sacrificed to environmental responsibility, or vice versa. The two strategies (lean and green) can be integrated and offered simultaneously that will reduce environmental or productivity inefficiencies (Pacific Northwest Pollution Prevention Resource Centre, 2008). According to Black et al. (2010) green manufacturing has the goal of zero waste. Yang et al. (2011) explores relationships between lean manufacturing practices, environmental management (e.g., environmental management practices and environmental performance) and business performance outcomes (e.g., market and financial performance). Torrielli et al. (2011) provides a broad perspective on combining lean manufacturing methods with environmental sustainability to assist foundries in remain competitive. They also demonstrates that environmentally sustainability solution can also reduce foundry operating cost. Bergmiller et al. (2009 a & c) suggests that “Lean and Green Programs” are synergistic and correlated. According to Bergmiller et al. (2009) the philosophical and structural similarities between models of leanness and greenness suggest that the reverse may also be true; i.e., those firms seeking minimal environmental impact from their operation may naturally adopt some methods of lean production in order to reduce wastage. According to Pacific Northwest Pollution Prevention Resource Center (2008), even without explicitly targeting environmental outcomes, lean efforts can yield substantial environmental benefits. Helper et al. (1997) explores how firms can be both profitable and environmentally conscious and how they can be both innovators in manufacturing and leaders in emissions reduction.

Since both Lean Manufacturing system models (Table 1) and Green Manufacturing system models (Table 2) tend to emphasize the significance of the manufacturing waste, its reduction tools and techniques and the achievement of expected business outcome, it has been recognised that there is a lot of similarity in the structure of such models. Table 3 shows combined Lean-Green manufacturing model.

**Table 3: Combined Lean and Green Manufacturing Model**

Lean/Green Manufacturing Waste	Lean / Green Waste Reduction Tools and Technique	Lean / Green Business Outcome
Overproduction	5 S	Improve Quality
Inventory of Raw Materials	5R(Reduce, Reuse, Recycle, Reproduce,	Reduce Cost

	Recovery)	
Work in Process Inventory(WIP)	Value Stream Mapping(VSM)	Right Time Delivery
Inventory of Finished Product	Kanban	Customer Satisfaction
Waiting of Equipment	Kaizen	Increase Profitability
Waiting of People	Pokayoke	Improve Productivity
Unnecessary Movement of Materials	SMED(Single Minute Exchange of Dies)	Reduce Lead Time
Unnecessary Movement of Finished Product	Takt Time	Reduce Pollution
Unnecessary Movement of Equipment	Just in Time	Optimum Use of Natural Resources
High Rework or Defects	Operator Care program	
Excessive scrap	ISO 9000/ISO14000	
High rejection	Total Productivity Maintenance(TPM)	
Frequent warranty claim	Total Quality Management(TQM)	
Lost people potential or Unused creativity	Process Redesign	
Poor Plant Layout	Product Redesign	
Pollution	Re-manufacturing	
Optimum Use of Resources	Waste Segregation	

**3. DISCUSSION**

This research addresses the integration of lean and green manufacturing concepts to the manufacturing industry. The objective is to look at commonalities between lean and green manufacturing where lean/green technique can reduce

- Both waste and pollution;
- Better inventory control;
- Better product quality;
- Increase profitability;
- Improve productivity;
- Reduce lead time;
- Optimum use of natural resources; and
- Better overall financial and operational procedures.

This objective can be achieved by developing guidelines for managing lean and green manufacturing flexibilities

simultaneously for successful realization of it for competitiveness.

#### 4. CONCLUSIONS

Lean and Green are the two powerful strategies for achieving operational and service excellence in any organization today. It is clear that lean manufacturing is a powerful tool that when adopted can create superior financial and operational outcomes. Literature discussed in this chapter covers all the facet of lean and green manufacturing including background and origin of the lean manufacturing, literature review of lean and green manufacturing and studies linking lean manufacturing methodology with green manufacturing. After having gone through the literature on lean and green manufacturing, it is concluded that there is gap in integration approach of lean and green manufacturing. There is need to bridge the gap between the theory and practice of Lean and Green (an integrated approach of Lean and Green) and the latest trends and research developments in both fields. Although these two methodologies have been around for several years, both aspects in research terms are required to be correlated.

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