

## SUSTAINABILITY: A NEW MANUFACTURING PARADIGM

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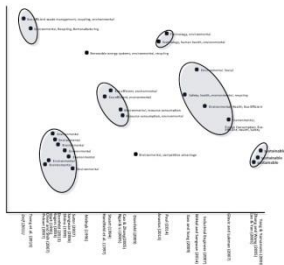
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### Graphical abstract



### Abstract

Recently, many industries adopted lean manufacturing philosophy to improve efficiency through reducing waste for maximization of profit. Most of the manufacturers have benefited the implementation of lean manufacturing through process effectiveness. However, despite of all its effectiveness in the production process, manufacturing industry is facing a real challenge instigated by the stakeholders (i.e. Customers, policy makers, regulatory authorities and society). Stakeholders are consistently pressurizing manufacturers to integrate the social and environmental factor within their production process to protect society and the environment from the negative effects of the manufacturing process, as a result manufacturing process experience continuous adaptation. This adaptation caused technological and procedural shifts, this significantly alter the fundamental manufacturing concepts. Current study provide the basic alterations in the fundamental principles of the green manufacturing paradigm, this adaptation ultimately leads to the new manufacturing paradigm of Sustainable manufacturing. Sustainable manufacturing is a broader concept of manufacturing focused on the integration of social, environmental and economic factors in manufacturing procedures.

Keywords: Lean manufacturing; social; environmental; manufacturing paradigm; green manufacturing; sustainable manufacturing

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## 1.0 INTRODUCTION

Over the years, the manufacturing industry has implemented programs to improve process effectiveness. Recently, many industries have adopted lean manufacturing philosophy to reduce the waste, increase efficiency, improving product quality, reducing cost and maximizing profit. Most of the manufacturers have benefited from implementation of lean manufacturing to increase process effectiveness [1-5]. However, despite of all its effectiveness in the production process, manufacturing industry is facing a real challenge instigated by the stakeholders (i.e. customers, policy makers, regulatory authorities and society). Stakeholders are consistently pressurizing manufacturers to integrate the social and

environmental factors in their production process to protect society and environment from negative effects of the manufacturing process, as a result manufacturing process experience continuous adaptation. Some companies are committed to reducing negative impacts of their operations on the environment [6-7]. Sometime, the resulting "Green" system creates reduction in energy consumption, waste generation, and hazardous materials used, thereby building the companies' image as a socially responsible organization.

The term "Green" initially was triggered by the environmental scientist and more related to considering the preservation of the natural environment during the production process. Recently, the term "Green" is more tilted towards a sustainable manufacturing. Sustainable

manufacturing is defined as a production process without compromising on natural environment, society and eco-efficiency throughout the product life cycle [8]. The fundamental change in the manufacturing industry refers to the paradigm shifts in the manufacturing industry. Current study aims to identify how current paradigm of green manufacturing is shifting towards the concept and implementation of sustainable manufacturing.

The term Paradigm shift refers to change in fundamental procedures or philosophies in any field. The term was coined by Thomas Kuhn (1962)[9]. He defined as a change in the basic assumptions or paradigms within the ruling theory of science. A modern dictionary definition of a paradigm shift is: 'a fundamental change in approach or underlying assumptions'. With respect to manufacturing, 'paradigm shift' means a significant change in the way one 'does' manufacturing. This new way of 'doing' manufacturing, is quite aligned to the new paradigm, is initiated by change in the set, or sets, of drivers that are forcing the change. Griffiths (2012) [10] has described that standards just like driving force to the paradigm shift in the manufacturing industry, and identify sustainability as a new manufacturing paradigm. Further research work has revealed that paradigms craft-Manufacturing, mass production, lean manufacture and a new paradigm 'un-manufacturing' paradigm, all are driven by sustainability standards. Lee et al., (2006) [11] have identified five manufacturing paradigms: mass, lean, time-based, mass-customization and agile. Where Nambiar (2010)[12]has pointed out manufacturing paradigm shift and identifies six: the Toyota production system, lean, quick response, agile and mass customization. Other researcher like Zhang et al., (2014)[13] have introduced new paradigm of Cloud Manufacturing based on computer aided manufacturing. It has created some climate of disagreement among manufacturing technology researchers to figure out that how many manufacturing paradigms never been explored yet so for in the body of knowledge.

## 2.0 GREEN MANUFACTURING

Lean offers organizations a toolbox full of methods that can be used to eliminate waste from business processes. Lean practitioners traditionally have focused on what they refer to as the "Eight Deadly Wastes": defects, overproduction, waiting, not utilizing people's creativity, transport, inventory, motion, and excessive processing [14-21], But what about environmental wastes? Often, they are simply neglected by lean practitioners, who may view environmental issues as not belonging in their domain. What are worse, environmental professionals historically have not been involved in their organizations' lean programs. This omission has led to cross-boundary problems. By refusing to pay

attention to environmental wastes, discharges, and emissions, lean programs can inadvertently create more of them [7].

Green manufacturing advocates cannot agree on a single definition of the green manufacturing. The term green manufacturing was initially related to the environmental protection from the harmful wastes of the manufacturing process, but with the evolution of technology and knowledge in the area term "green" no more related to the environmental effects only. Table 1 briefly explains the definitions of the different researchers in the area of Green Manufacturing.

Annexure 1 highlighted the use of technology for reducing the environmental harms. In this regards many technological innovations has been utilized like the concept of remanufacturing, manufacturing, recycling, energy efficiency etc. these technologies somehow reduce the negative affect of the production process on the environment. However, the social aspect of the sustainability is still neglected. The difference among concept an operationalization of the green manufacturing technology led manufacturing industry towards the implementations of sustainable manufacturing practices.

## 3.0 SUSTAINABLE MANUFACTURING: A NEW MANUFACTURING PARADIGM

Annexure 2 highlights during the process of concept mapping from the literature about the term green manufacturing some interesting facts have been found. First, there is no single definition of green manufacturing exists currently in literature on which researcher have made consensus. Some group of authors has been emerged during the process. A group of Green manufacturing advocates contemplates green manufacturing as the integration of Environmental factor in manufacturing practices to preserve the natural environment from the harmful effects of the manufacturing process [e.g. [22-29]. Another group of researchers have argued that integrating social factor is also crucial to get maximum environmental and social protection from manufacturing outcome that can damage Society and environment [30].

Another prominent group of researchers have argued that green manufacturing is not only considering social and environmental factors during manufacturing, but it is a science to improve manufacturing process in all respects of society, environment, making it more eco-efficient through using and recyclable products with low energy and resource consumptions [e.g.[7, 24, 31-34]. another view of green manufacturing advocates is focus on the human health and safety[35]. The Most recent development of the researchers have suggest that green manufacturing is a process of taking into account social, environmental, economic and technological factors during the manufacturing

process to conserve the natural environment and society.

### 4.0 CONCLUSION

The literature review has highlighted the pitfall pattern of manufacturing process occur during transformation of paradigms shifts. A Conclusion has been drawn on the basis of literature review that transformation processes went through significant variations during the paradigm shifts. In nutshell this section would highlight the modifications in the work design practices related to the lean and sustainable manufacturing paradigms.

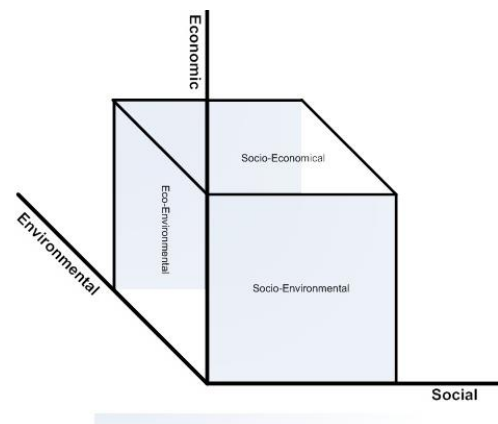
Defining sustainable manufacturing, process concepts and concerns leads to changing in manufacturing dimensions. How does it challenge the basic rules and theories of other manufacturing paradigms? Table 1 shows the process consideration of lean, green and sustainable manufacturing.

**Table 1** Process Trepidations and Manufacturing Paradigms

Factor	Process thinking	Lean	Green	Sustainable
Economy	Overproduction	√	√	√
	Defects	√	√	√
	Unnecessary Motion	√	√	√
	Unnecessary Inventory	√	√	√
	Resource Consumption	√	√	√
	Inappropriate processing	√	√	√
	Transportation	√	√	√
	Waiting	√	√	√
	Lost People Potential	√	√	√
	Environmental	Process Redesign		
Product Redesign				√
Recycling				√
Remanufacturing				√
Consume Internally		√	√	√
Prolong Use				√
Returnable Packaging				√
Spreading Risks				√
Greenhouse Gases			√	√
Solid waste			√	√
Liquid waste			√	√
Eutrophication			√	√
Pollution			√	√
Rubbish			√	√
Social	Workers Health	√	√	√
	Workers Safety	√	√	√
	Society Health concerns		√	√
	Society Safety Concerns		√	√
	Cross Functional	√	√	√

	Teams			
	Workers participation	√	√	√
	Workers Respect	√	√	√
	Social Context			√
	Technology Advancement	√	√	√
Technological	Technology Conservation			√
	Scio-technical	√	√	√
	Quality Management	√	√	√
	Continuous improvement	√	√	√

Table 1 shows the social, economic, environmental and technological consideration during the sustainable manufacturing process. Table provides a comparison of the work practices during the each paradigm. It can be noticed that lean manufacturing focus on the eliminating the waste from the process to improve the effectiveness and respect for employee and their health concerns are essence of the LP. However, LP fails to determine the work practices and process concern which are required to reduce the environmental damage. This need requires significant alterations in the manufacturing process and technology. Green manufacturing on the other hand, provides the tools and techniques to protect environment, but the focus of the green manufacturing is more towards the environment if comparing with the sustainable manufacturing paradigm which based on the protection of the triple bottom line, i.e. economy, environment and society.



**Figure 1** Sustainable manufacturing cube

Figure 1 explains the concept of sustainable manufacturing and its process concern based on integration of economic, environmental and social factors during manufacturing. From the above cube the sustainable manufacturing paradigm could be defined as manufacturing process that integrate social, environmental and economic factors within production process to produce and extend the life

cycle of the product through utilization of technology that is safe for the stakeholders and with minimum wastage of resources so future generation can meet their requirements.

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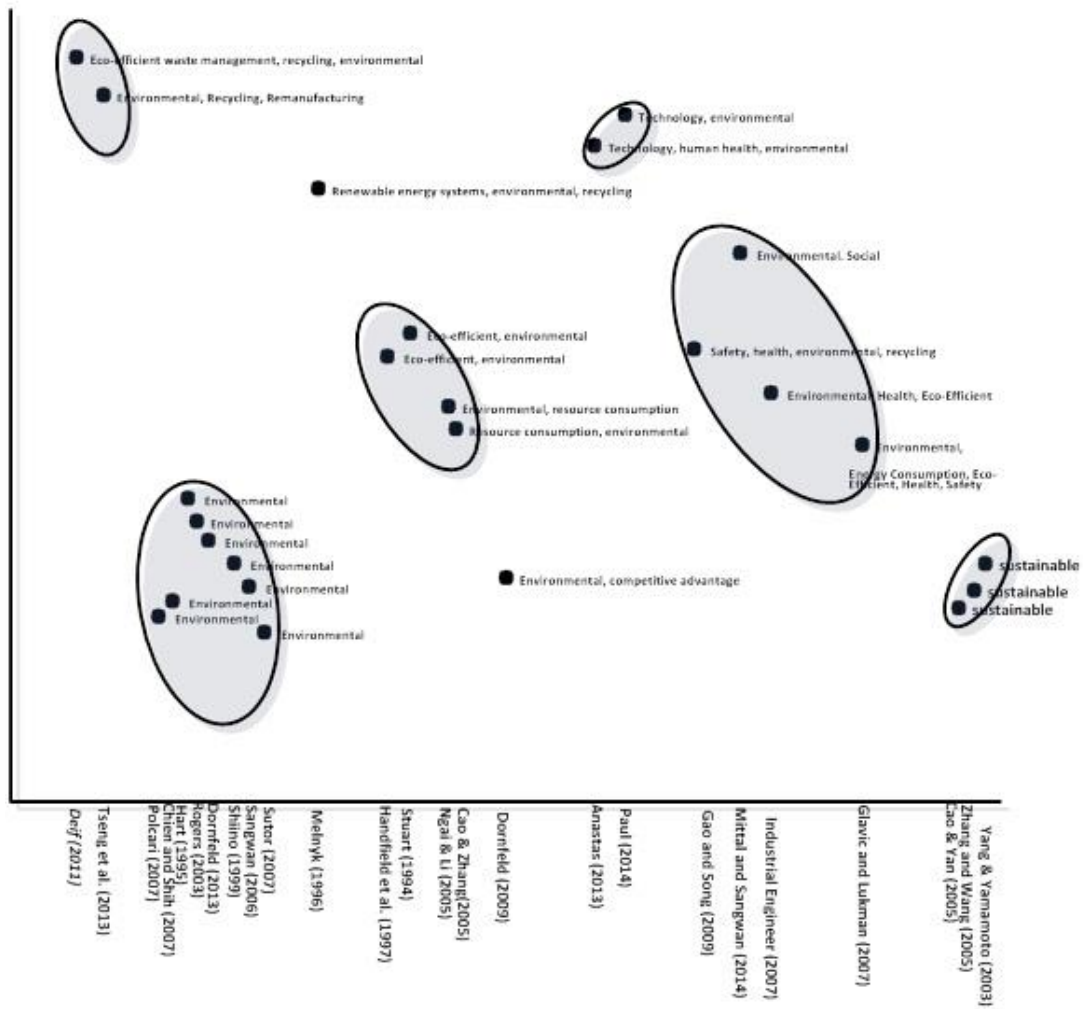
Repairing the fabricated mosaic. *Journal of Cleaner Production*.

## Annexure 1

Annexure 1 Green Manufacturing defined

Author	Theme	Process Concerns
Deif (2011) [7]	eco-efficient through waste management, recycling and environmental friendly production	eco-efficient management, waste recycling, environmental
Tseng, et al., (2013)[31]	Design for environment (DfE), Remanufacturing, Recycling, and Cleaner Production for environment preservation.	Environmental, Recycling, Remanufacturing
Hart (1995)[22]	environmental perspective value chain	environmental
Rogers, Seddon, and Volkov (2003)[23]	prevent pollution and save energy reduces and/or eliminates the use or generation of hazardous substances	environmental
Hart (1994)[22]	business strategy that focuses on profitability through environmentally friendly for competitive advantage	eco-efficient, environmental
Melnyk and Smith (1996)[32]	renewable energy systems and clean technology, recycling and reusing	renewable energy systems, environmental, recycling
Dornfeld (2013) [24]	environmentalism and tending to preserve environmental quality	Environmental
Mittal (2006) [30]	Minimize negative effect on environment and society	Environmental. Social
Dornfeld, et al., (2013) [24]	environmental consciousness in manufacturing use of remanufacture, reduce, and reuse/recycle	Environmental, remanufacture, recycle
Shiino (1999)[25]	Environmental Protection	Environmental
Sangwan (2006) [36]	Manufacturing with environmental issues and concerns	Environmental
Zhang and Wang (2005)[13]	sustainable science to the manufacturing industry	Sustainable
Chien and Shih (2007)[27]	minimize the environmental impact	Environmental
Liu, Chen, Kang, Ngai and Li (2005)[33]	Environmental impact and the resource consumption	Environmental, resource consumption
Polcari (2007)[28]	Environmentally benign practices	Environmental
Liu, Yin, Cao and Yan (2005) [33]	sustainable development	Sustainable
Sutor (2007)[29]	Minimize Negative impact on the environment	Environmental,
Industrial Engineer (2007)[35]	Producing economical products which produce minimum pollution and health issues	Environmental, Health, co-Efficient
He, Liu, Cao and Zhang (2005)[34]	consideration resource consumption and the environmental impact	Resource consumption, environmental
Glavic and Lukman (2007) [37]	non-polluting, that conserve energy and natural resources in economically viable, safe and healthy ways for employees, communities, and consumers	Environmental, Energy Consumption, Eco-Efficient, Health, safety

Annexure 2



Annexure 2 Concept Mapping for Green Manufacturing