LEAN AND GREEN MANUFACTURING: A LITERATURE REVIEW

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Abstract: *The main focus of this paper is to evaluate the past literature work on the relationship and implementation of lean and green manufacturing. Many researchers have been developed many frameworks which has been discussed here. This study will help to understand the practice of Lean are more beneficial with Green as well as green manufacturing can be best combined with lean. This study provides the opportunities for different firms to use lean framework as a medium to make their process Green. This paper provides a sufficient literature to show that the lean practices are beneficial for Green practices.*

Introduction

From the past few years many researcher and experts have investigated about the relationship between lean and green practices. As Womack and Jones (1996) mentioned: „Lean thinking must be „green" because it reduces the amount of energy and wasted by-products required to produce a given product". Zhu et al. (2008) investigated the construct and scale for evaluation of green supply chain management acceptance in terms of implementation among manufacturers. With the help of data collected from 341chinese manufacturer, green supply chain management practice implementation was measured. This study emphasized the synergic effect of environmental and supply chain management on competitive and global dimensions which is mostly unnoticed by firms.

Walton et al. (2002) has described several dimensions of changes through the increase in purchasing on environmental issues. These changes includes the material used in product design in terms of environment, product design, supplier involvement , evaluation of supplier and inbound logistics. Espadinha-Cruz et al. (2011) this paper emphasized the impact of Lean, Agile, Resilient and Green to gain the competitiveness towards the demand of global markets. The integration of these four management approaches on supply chain is plays a great important role, but also challenging. This study presents a methodology for analyzing the interoperability in Lean, Agile, Resilient and Green approaches in SC industrial sectors such as automobiles.

Folinas et al. (2013) In this paper researcher has used the lean thinking technique to identify the major sources of waste in the concerned supply chain. Value stream mapping has been used for the detection of waste, mainly focused to measure the carbon dioxide emission across the organizational area. Author also suggested that lean is an effective tool for the identification of problems that is responsible for the emission in the supply chain. Author also has provided a detailed procedure that how companies could use the lean principles in their organizations. The conclusion of research drawn, was that five lean principles are mandatory to be implemented for benefits of company. These includes- 1. Re define value, 2. Map process activities & value stream, 3. Detect waste, 4. Develop an Ideal state of production and supply chain operations, 5. Control lean operations. The main objective of this was to propose a systematic approach to measure the environmental performance of supply chain in a food case study.

Literature review

Peter Hines (Hines, 2009) has classified the Green Muda into 8 types. These are greenhouse gases, eutrophication, and usage of resources in an excessive amount, usage of power in excess, pollution, usage of water in excess, poor health and safety. This paper provides the correlations between lean and green wastes and corresponding tools to eliminate them.

Hajmohammad et al. (2013) proposed a conceptual framework in which the environmental practices depicts the relationship between lean and supply chain with regards to the environmental performance. For testing the model a plant level survey also has been conducted in a Canadian manufacturing plant. The conceptual model suggested that lean management and supply management can have an indirect effect on environmental performance. Many researcher have investigated the integration of environmental issues into supply management (Vachon and Klassen, 2006; Zhu and Sarkis, 2004). Dües et al. (2013) in many organization managers objective is to integrate the lean and green principles into their working operations. The main question arises here is „How?”, „How can a lean practice be used for greening the supply chain?” Or we can say that without any large investments or any typical extensive changes in supply chain, can we generates profit in an environmental way? For the integration of lean and Green in an organization, it is mandatory to understand the distinguishing attributes of two practices.

Fercoq et al. (2013) Proposed a framework in three level to optimize a waste minimization program, level 1 includes integrated improvement process, level 2 includes strategic matrix and a toolkit, and level 3 includes advanced 3R(Reduction, Reuse, Recovery methods). The Integrated improvement process comprises of seven phases: Strategy – Identify – Measure – Analyze – Improve – Implement - Control. The Strategic matrix have four 4 possible objective for the improvement plan: Eco-efficiency, Eco-responsibility, Eco- partnership – Eco sharing. The integrated toolkit specifically for Lean Green tools, Phases are- Identify – Measure – Analyze – Improve. The last level Advanced 3R method include a six step sequence for analyze and improvement. For the integration of lean and green, Eco efficiency plays an important role. It aims to reduce the consumption of resources like water, energy or any raw materials, as well as to reduce the impact on the environment like carbon dioxide emission, air and waterborne emissions, disposal of waste and dispersion of harmful substance.

Verrier et al. (2016) this paper provides an implementation structure for a lean and green methodology based on previous literatures and removal of wastes in production process. This research has been conducted along the Lean and Green project (Verrier el al. 2014). The main aim of this paper is to find a suitable way to integrate and implement the Lean and Green tools and methodologies within an organizations that have variation is their organization culture and in the process.

Abreu et al. (2017) Lean Green is a concept that contributes towards the value enhancement and efficiency in the organizational and environmental terms. Lean Green inspire the organizations to set their goals and strategies to add more value in product as well as while doing it take care about the environmental practice. The eco efficiency idea is to create/produce more with less. In this paper author has analyzed 27 model with a single aim that which can be considered as a Lean Green Model.

The eco efficiency concept comprises of conservation of resources and these can be classified as- a) reduction in the intensity of raw materials, b) reduction in the energy intensity, c) reduction in toxicity of substance in terms of quantity and level,

d) enhancement of renewables, abundant and local resources, e) usage of durable products, f) intensifying the use of services.

Mittal et al. (2017) in the new era of world every industry wants to cooperate the increasing customer choices, environment concern and to be competitive in market. The modern manufacturing systems comprises of three dimensions economic, environmental and social. This research integrates the Lean, Green and Agile manufacturing in a manufacturing system. The adoption of lean- green- Agile manufacturing system would be encouraged by few enablers. This paper identifies 10 enablers with the help of academic and industry professionals for (Lean Green agile manufacturing System) LGAMS.

Ruiz-Benitez et al. (2017) in this paper researcher illustrate the impact of lean, Green and resilient supply chain on environmental performance. For this purpose a special case study of aerospace has done. In this two methodology has been used for the identification of relationships map between practice and performance measures. These two methodology are Interpretive Structural Modeling (ISM) Approach and Importance Performance Analysis (IPA) techniques.

As per the study Lean Supply chain represents a methodology which is basically focused on waste reduction, cost minimization and flexibility in the whole processes starting from design to sale of product. Green supply chain comprises of environmental effects into a value chain by the implementation of green activities like green design, green purchasing, reduction in carbon emission, involvement of supplier for environmental collaborations and also involvement of customer for environmental collaborations. Green SCM practice provides the organization to achieve a long term benefits like increment in market share and profit by the environmental practices and also to improve ecological efficiency.

Ramos et al. (2017) from the past studies it is clearly shows that government policies and current production system has adding the environmental impact in their production process and also it is promoting the other organizations to achieve sustainable competitive advantages. Study shows that lean manufacturing and Cleaner production has made a powerful contribution in terms of environmental performance of companies. This research has proposed a Lean Cleaner Production Benchmarking (LCPB) method to measure the practice and culture regarding the application of Cleaner Production in organization. Cleaner production in an organization refers to the application of triple bottom line i.e. economic, environmental and technological strategy to the products and process to use the raw material, water and energy efficiently through recycling, minimization and non-generation. Cleaner production focused on preventive actions to reduce the negative impact on environment.

Lean and Green waste

Lean and green are two concept which when work together can be produce a product with a high quality and less cost without any degradation in terms of environment performance. Generally lean is a system which is focused to customer requirement and satisfied by minimum cost and less lead time. In green customer are looking for a product that help to produce in more environmental friendly way. Lean focused on best performance and practice by the organization while green concept encouraged the life cycle assessment to design the product so that each process in production would be environmental friendly. Green manufacturing focused on reduction of wastes which are harmful for the environment such as increase in CO2 emissions, waste of water, air pollution etc.

Womack and Jones identified the waste into eight types. These are

Defects – Errors in production, Scrap/ Rework, problem in quality of product, frequent errors in production/ process/ raw materials.

Overproduction- Excess in inventory, production in a high amount results into poor information flow.

Waiting – waiting by worker, material and machine resulted in a long lead time.

Non Utilization/ Underutilization – Non utilized people skill, unused creativity and experience of employee.

Transportation – Unnecessary movement of material, worker results in long waiting time and lead time also.

Inventory – Extra storage of material, finished product results in high investment.

Motion- Poor arrangement of workplace result in extra motion by worker.

Excessive operations – Inappropriate processing not required for product, using a special machine or method where simple approach can be suitable.

As lean manufacturing wastes are accepted by all over the world, Peter Hines has described the eight green manufacturing wastes which is inspired by lean. According to him green wastes are- Greenhouse gases, Excessive resource usage, Excessive power usage, eutrophication, pollution, rubbish, poor health and safety, excessive water usage.

This paper focuses on wastes defined in lean and green manufacturing as well the possible tools that can be used to eliminate them.

Through the meta-analysis of previous literature, we can correlate the wastes in lean and green manufacturing in next section.

Lean Mudas	**Green Mudas**
Defects	-Waste of energy as well as raw material used for product. - management of re-treatment
Overproduction	Unnecessary use of energy, raw material, water etc.
Waiting	Wastage of potential, spoiled energy and resources
Non Utilization/ Underutilization	Lost potential for improvement
Transportation	Usage of energy in transport, Emission in the air while transportation
Inventory	Excessive power usage for storage e.g. heating, cooling, lighting Extra usage of material for packaging, to reduce deterioration.
Motion	Potential more space (energy)
Excessive operation	Unnecessary energy and raw material usage, sometime rubbish and emission.

From the literature some points have been found out with regards to lean supply chain.

1. Lean mainly focused on waste reduction process such as inventory reduction, buffer capacity and material reduction so that the production should be as much as needed i.e. pull production and it focuses on reduction in defects and errors which result in wastes through the use of lean tools such as TPM, TQM, 5S, Value Stream Mapping etc.
2. Involvement of suppliers in practices results in lead time reduction, close relationship with suppliers and no intermediators between supplier and organization means direct deliveries.
3. Lean proposes a system of people involvement and continuous improvement workplace in the production process with the environment of proper training and educations.
4. For the reduction in times such as set up time or cycle time some concept has been used such as one piece flow, just in time etc.

Similarly few points can be summarized about green supply chain

1. Green supply chain encouraged the monitoring practices such as monitoring supplier practices and policies.
2. Green system involve the certification to reduce waste such as ISO 14000 certification, Green purchasing, reduction of pollution and waste which are harmful for environment.
3. Green proposes a development model which includes the recycle of materials, design or production of materials which can be reuse and recycled.

Jim Womack wrote that Lean thinking must be green because it help to reduce the amount of energy wasted by- products required to produce a given product. It means it reduces human efforts, space and scrap by fifty percent or more, per produced product, through lean principles.

Lean can be explained as a concept which understand the customer’s needs and reviewing the value stream, to reduce the eight wastes.

Green can be explained as a concept which understand the society’s needs and reviewing the system, to reduce green wastes.

Methodology

The study of lean and green manufacturing is a little theoretical in background. The main focus of this research consist of systematic review, meta- analysis of literature and identification of relationship between lean and green system.

The main objective was to explore the work that has already been done previously by researchers. Many researcher have given framework for the lean and green practices in organizations. This study is trying to find out the possible framework already described by the researchers.

The review of literature has started with the identification of keywords for search. For the searching of literature few single has been used these are ‘Lean’, ‘Green’, ‘Lean and green’, ‘Lean supply chain’, ‘Green manufacturing’ , ‘Sustainability’, ‘Green supply chain management’, ‘Lean green supply chain, ’Sustainable VSM’ and many more similar terminology. Firstly the single words has been used as keyword for searching and afterwards string using the combination of words.

After the searching of articles, each articles abstract was read and evaluated to make the decision whether this article fit into the requirement of study. If it suitable then it will be added in study. Articles has been classified in three categories. Category ‘A’ for articles that are directly relevant, Category ‘B’ for articles that are relatively but not directly relevant and Category ‘C’ that are useful but not relevant for this particular study.

Research findings

Lean and Green manufacturing both are having different attributes. Lean and Green manufacturing can be described by a comparison on purpose, aim, customer satisfaction perspective and organizational structure.

The analysis of research finding described the connection between two concepts. The data defined the area where these strategies can be implemented individually and combined.

Similarities between lean and green

Lean and green concept having many common attributes like waste reduction, lead time reduction, people involvement, service level and many tools etc. The main common attribute was waste elimination as it required in both concepts. However waste is defined as differently in both concepts. For lean waste has been classified into 8 types already discussed. Whereas green focuses the wastes who are responsible to harm the environment.

Attribute	**Lean**	**Green**
Purpose of Concept	Maximize profits, reduce the cost by waste reduction.	Reduction of harmful emission as well as to reduce the environmental risk, improve the ecological efficiency.
Main Aim	Minimization of cost through elimination of waste with lean tools	Achieve the sustainable development and reduce the environmental harmful activity through elimination of ecological wastes and pollution.
Customer Satisfaction	Mainly the customer for the organizations who needs the product at low cost with high quality.	Mainly the customer who needs the product without any harmful activity to environment (e.g. ISO 14000) that uses employee involvement.
Lead Time	Focuses to reduce the lead time so help to improve the productivity.	Reduce lead time through less transportation so as it will reduce the CO2 emission.
Relationship with customers as well as supplier	It focuses on the voice of customer so produces a product of customer needs as well incorporated the supplier involvement to produce the product with less lead time.	It focuses on inter-organizational collaboration to transfer the green knowledge to each partners, suppliers and customers.
Product design	High quality and minimum cost.	Product with Eco Design and also incorporate the life cycle assessment to evaluate the environmental risk and impact.
Selection of raw material and manufacturing	Purchasing of product with low cost and high quality, using JIT system pulling so less inventory.	Green purchasing of product. Material which are reusable and remanufactured are used.

Inventory	Keeps less inventory to reduce cost and to generate high turnover.	Also keeps less inventory to free up the space and save energy
Transport	Reduces the transportation, encourages the frequent supply of product in small deliveries.	Reduce the transportation frequency to reduce the CO2 emission as well as to reduce the fuel consumption.
Product termination	It refers to the end of sale of product, no concern about the product life after use.	Concerned about the product life cycle. It should be recycled or remanufactured.
Organization profits	Quality, Cost, Delivery, customer satisfaction, productivity, profitability.	Quality, Cost, Delivery, Customer satisfaction, Process waste, CO2, Cost for future generation.
Main Tools	Value Stream Mapping, TPM,JIT, 5S, Kaizen, One Piece Flow, standardization, TQM etc.	Life cycle assessment, all the certification related to product standardized in terms of environmental friendly.

Some of the articles has been selected for their contribution towards selection of framework for green lean supply chain management.

Espadinha-Cruz et al. (2011) this research presented a model which deals to evaluate the overall business interoperability and also presented the measures that can reduce the interoperability problems in the supply chain. Interoperability is problem faced in supply chain while using the some technologies together such as Lean, Agile, Resilient and Green.

LARG supply chain’s interoperable practices are divided into 5 parts. Business strategy, Organizational structure, Employee and work culture, Collaborative business process and Management of external Relationship.

Business Strategy – 1-Clarity in Strategic Goal s and 2-Impacts in Collaboration Breakdown;

Organizational Structures – 1-Cross- organizational Mapping and 2-Contact points;

Employees and Work Culture 1. -Linguistic barriers, 2-Motivation, 3-Responsibility, 4-Honesty and 5-Efficiency;

Collaborative Business Process 1-Responsibility sharing, 2-Clarity in Business Processes and 3-Visibility;

Management of External Relationships 1-Partner selection, 2-Partner Assessment, 3- Cooperation Contracts, 4-Conflict Resolution and 5-Communicatio.

Hajmohammad et al. (2013) Nowadays firms are getting high pressure to maintain their firms activity be sustainable and integrate the environmental and social dimension in their product designs. This paper proposed a conceptual model which help to understand the role of lean and supply chain management to improve the firm’s environment performance. Canadian manufacturing plant has been used to validate the model.

Supply management - 1 Supplier development programs 2 Suppliers evaluation 3 Suppliers’ facilities auditing activities 4 Suppliers recognition 5 Suppliers certification process.

Lean management - 1 Just-In-Time (JIT) 2 Manufacturing throughput time reduction 3 Setup time reduction 4 Total Quality Management (TQM).

Environmental practices - 1 ISO 14001 certification 2 Pollution prevention 3 Recycling of materials 4 Waste reduction.

Environmental performance – 1 Air emissions 2 Waste water generation 3 Solid wastes disposal 4 Consumption of hazardous/harmful/toxic materials 5 Energy consumption Plant size.

Abreu et al. (2017) Lean green concept has been widely used by the organization in the past few years. Lean and green concepts associates with the value aggregation and improvement in efficiency in environmental and organizational terms. The eco efficiency models generally refers the idea of producing more with less to reduce the environmental impacts and harmful activity. This paper provide the model for lean and green integration by the previous literature.

Verrier et al. (2016) this paper highlights the lean and Green house and also the tools that can be help to reduce the wastes (Lean and Green mudas). The paper also presented a CMMI based Lean and Green maturity Model. „Lean and Green Project”, this paper provides an implementation structure base on the wastes extracted from the production process base on lean and green manufacturing. This paper also presented the results which is gathered and defined in lean and green house. The last section presents a detailed Capability Maturity Model Integration (CMMI)-based Lean and Green maturity model.

Lean and Green house -

1. Top down management (driving process)
2. Bottom up exercise or feedback (genchi genbutsu) – correct information to back to management
3. Continuous improvement
4. Lean – 5S
5. Human workforce - Safety
6. Green – control of hazardous substances
7. Value stream mapping and Gemba walk Tracking of wastage
8. Monitoring process indicator Visual management
9. Quality
10. Enhancement of skill and motivation
11. Reduce and reuse
12. Employees involvement
13. Supply chain relationship
14. Proactive knowledge
15. Proactive compliance
16. Lean and green strategic sustainability.

Mittal et al. (2017) Modern manufacturing system has been categorized in three dimension economic, environmental and social. This paper attempted to prioritize the enablers for lean green agile manufacturing system. They have divided the lean green agile manufacturing into these three dimension. According to paper agile manufacturing should be used at product level which comes under social dimension. Lean manufacturing should be applied at systems’ level which comes under economic dimension. Green manufacturing will applied at process level and it comes under environmental dimension.

Researcher has divided into 10 enablers. These are supplier Involvement, Top Management Commitment, Flexible Work Force, Human Resource Management, Flexible

Work place, Customer focus, Customer Feedback System, Information technology Integration, Resource optimization, Product life cycle management.

Ruiz-Benitez et al. (2017) this paper also describe the relationship and links among lean, green and resilient supply chain practice and impact on environmental performance. Two methodology has been used to identify the relationship map between practices and performance measure.

Lean supply chain management practices 1 Supplier selection, evaluating and monitoring. 2 Suppliers and company involvement in NPD (New Product Development) 3 Communication and information exchange between suppliers and company 4 Electronic-enabled supply chains. 5 JIT delivery practices. 6 Pull production systems. 7 Value stream mapping (VSM). 8 Training in lean initiatives.

Green supply chain practice - 1 Joint planning 2 Cooperation with suppliers to solve end-of-pipe environmental issues 3 Cooperation to minimize logistical impact of material flow 4 Environmental collaboration with suppliers 5 Environmental monitoring upon suppliers 6 Green procurement/sourcing 7 Prequalification of suppliers 8 Communication of environmental criteria for goods and services 9 To encourage suppliers to take back packaging 10 To use recyclable pallet to delivery materials 11 Collaboration with suppliers in product design to reduce and eliminate product environmental impacts 12 Communication and collaborative approaches to foster environmental improvements across the SC 13 Suppliers environmental management systems requirement 14 Supplier education, coaching and mentoring

Resilient supply chain practices – 1 Use of information control systems 2 Communication and information sharing with suppliers 3 Flexible supply base 4 Core firm pays a proportion of costs derived from their supplier/s get/s redundancy 5 More mutually beneficial agreements between core firm and their suppliers with clearly stated incentives and obligations across time 6 Improve visibility, collaboration, coordination and understanding with suppliers 7 Maintaining excess capacity in productions, storage, handling and/or transport. 8 Enforce security 9 Contingency planning 10 Disaster recovery plan 11 Alternative transportation routing 12 Visible transportation.

Ramos et al. (2017) Lean manufacturing and cleaner production are the two concept which have contributed towards the environmental performance of organizations. In this paper lean cleaner production benchmarking (LCPB) method has been used to assess the practices and culture regarding the application of cleaner production in organizations. This method help to relate the lean manufacturing and cleaner production activities. The Lean Cleaner Production Benchmarking (LCPB**)** method is structured based on six variables that have been identified as fundamental to the successful implementation of CP. These variables include (1) Management/Responsibility; (2) People; (3) Information; (4) Supplier/Organization/Customer; (5) Product Development; and (6) Production Process.

Gandhi et al. (2018) this paper provides the drivers for lean and green manufacturing identified from the existing literature as well from the experts’ opinions in the respective fields.

Drivers for lean manufacturing

1. Employee Involvement – Provide the proper knowledge and awareness about lean concept and tools.
2. Top management commitment – commitment by management towards lean organization.
3. Workers with multi skill – multi skilled worker can enhance the productivity of organization.
4. Reduction in machine breakdowns – Able to produce in less lead time as well as less defects.
5. Standardization – work standardization help to improve the rate of production and also improve the safety for employees.
6. Organizational culture – Working environment should be more cooperative and lean oriented.

Drivers for green manufacturing

1. Top management commitment – commitment by management towards green manufacturing.
2. High level technology – organization must involve the best advanced method to use energy and methods to use resources efficiently.
3. Saving of energy and cost – Encouragement of energy saving results in saving in terms of cost.
4. Competitive advantage – saving cost.
5. Current legislation – Pollution control, Landfill taxes, Emission norms
6. Future legislation – Expected initiation of new laws, increased level of enforcement.
7. Incentives – Environment with a positive support.
8. Green process – environment friendly approach to help the society.
9. Pressure by government and people – Government policies, media, NGO’s and social worker.

Conclusion

As per the current climate change scenario, most of the firms find themselves in a pressure to incorporate the environmental responsible process in their organizations. The main focus of this paper is to identify the relationship between lean and green manufacturing as well as to identify the frameworks already discussed by previous researcher. This paper also identifies the potential areas in organization in which green and lean practice can be applied together. It is necessary to know the basic attributes which defined the interrelationship between lean and green manufacturing. Lean and green manufacturing comprises of many similar attributes such as waste reduction, people involvement and safety, reduction in lead times and also share tools and practices. Research shows that lean is very beneficial for green practices and green manufacturing also results in positive influence on business practices.

The difference in lean and green concept lie in their focus, lean mainly considered to improve the quality of product by elimination of waste and cost minimization while green focuses of product design and manufacturing strategy, end of product life cycle. Product should be reusable, re-manufacture and also recycle. The research suggest that lean practices serves as a catalyst to green practices. The integration of lean and green is beneficial for any organization as well as for environment.

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