

Learning on Lean Production: A Review of Opinion and Research within Environmental Constraints

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ABSTRACT

Despite of its type, location or principal market base, today the manufacturing enterprises are bound to adopt sustainable practices like lean principles, integration of processes and inter-organizational collaborations to meet their corporate goals. The majority of studies usually discuss either a system or a subcomponent of the production systems and manufacturing strategies in literature w.r.t. lean production; but the rational (what, why, how) behind each production activity seems to be missing. This paper addresses a comprehensive assessment of the literature on lean production in relation to the green concept, for its significance, feasibility and need for organizations to sustain in the global market. Findings of the review reveal that lean principles along with green model can improve the process flow & employee morale and lower the environmental regulatory non-compliance risk. Further, the environmental and human health risks are often not explicitly considered in lean initiatives that can affect customers & stakeholders throughout the product life cycle, and the manufacturing enterprises working with lean strategies have the possibility of costs sub-optimization and waste reduction from a lifecycle viewpoint.

Keywords: *environment, lean production, sustainability, wastes*

1. INTRODUCTION

While considering the rest of world in their competitive strategy analysis, the enterprises cannot isolate the external factors such as economic trends, competitive positions or technology advancement; and the major factor to remain competitive in the industrial environment of varying needs is the effective & efficient operation of customized manufacturing system, as well as its ability to quickly re-organize the system for new product introduction. One such set of tools 'lean manufacturing' causes work in a process to be executed with least non-value adding activities (NVAs) and hidden wastes, focusing on quickly meeting the customer demands at minimum time & cost. Toyota production system (TPS) commenced the lean principles in

1950 in Japan (Womack *et al.*, 1990), as a set of practices & methodologies that leads to cost reduction. Lean manufacturing (LM) was originally applied to the automotive sector, but Baines *et al.* (2006) illuminated that lean principles could also be transferred readily to other production functions and sectors. LM principles involve defining customer value, making customer pull the product, value stream and making it flow, and striving for excellence (Jensen *et al.*, 2007). For lean, the continuous improvement feature becomes the compelling power for researchers to discover it further for products and machine tools, concentrating at not only dipping but eliminating all forms of NVA work in production system and improving overall productivity by adding customer value (Figure 1). LM is identified for its focus on reduction of the Toyota's eight types of wastes (Dimitrov *et al.*, 2012) where waste is anything that does not add value to the end product as of customer viewpoint (Meyers *et al.*, 2002). These recognized wastes in TPS are transportation, overproduction, waiting, over processing, motion, defects and unutilized or unused creativity. Thus, LM can be defined as a systematic approach to recognize and eradicate waste through continuous improvement by making the product run at customer demand (Syed *et al.*, 2011). Lean production involves respect for people, a level of patience, continual improvement and a focus on process & ability to realize the individual development (Liker, 2004). The two pillars of TPS are continual improvement (i.e. Kaizen) and respect for people, and these tools are designed to make it simple to see problems, easy to resolve them and easy to learn from mistakes.

Being the system thinkers, an industrial engineer's approach to ecologically-responsible designs & manufacturing practices must incorporate the employee, environment and their interaction for optimal ergonomic efficiency with least disturbance to the environment. Mr. Suzuki, senior environmental official at Honda, studied whether lean practices help to achieve environmental performance or they are obstacles, and he believed that lean stresses on the abilities of individual worker rather than

viewing them as an extension of production system. Seuring *et al.* (2004) indicated that in the last decades environmental questions became a critical issue for governments and enterprises; moreover it has become a concept that polluting environment could harm the company image among consumers, what could adversely affect profitability & sales, and now the ecological challenges are no longer limited to the manufacturing walls. Pusavec *et al.* (2010) described the evolution of four production systems according to their environmental practices as:

- a) Traditional production systems- based on disposal of wastes as a principle;
- b) Lean production systems- waste reduction for better resource utilization;
- c) Green production systems- apply the 3 R's principle (Reduce, Reutilize or Recycle wastes);
- d) Sustainable production systems- apply the 6 R's principle (Reduce, Reutilize, Recycle, Recover, Redesign and Re-manufacture).

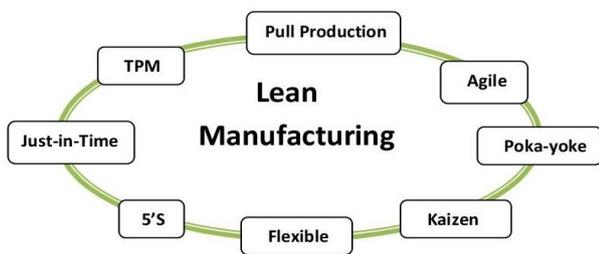


Figure 1 Lean Manufacturing

Though, one weakness of lean is that, regardless of the process approach that aims at reducing the risk of sub-optimization, it primarily focuses on the production part of the lifecycle, and an organization working with this approach risks sub-optimization of costs from a life-cycle perspective. When companies have limited time and resources, efforts should be placed where they contribute the most, which is not always in the production phase. Another potential weakness of lean is that Just-in-Time (JIT) can lead to increased shipment, as pointed out by Whitelegg (1994) and Bleijenberg (1996), this is however not perceived as a problem by the interviewed companies as transport is strongly linked to costs that can be very low through proper planning and managing the transports. Larson *et al.* (2004) revealed that lean can lead to a lack of consideration of ecological risk, that the companies' activities may cause risk remaining hidden.

1.1 Need for Lean and Environment Integration

Clearly considering the environmental goals and opportunities in implementation, lean improves process flow, lowers the regulatory non-compliance risk and improves employee morale which is only possible with full regulatory obligations. Currently, there is an emphasis on lean thinking surrounded by the environment, health & safety as well (Brewer *et al.*, 2012), and adopting green practices are not only good for sustainability reasons but are also good business (Green Manufacturing, 2008). Studies show that the 'envi-lean' integration is not only possible but also advantageous from business and an environmental

viewpoint while reducing the risk of sub-optimization and synergies can be achieved (Gadekar, 2015; Bergmiller *et al.*, 2009; Puvanasvaran *et al.*, 2012). Larson *et al.* (2004) found that combining lean & environmental methods is not only possible, but it also offers the potential to gain competitive advantages and environmental sustainability. Furthermore, combining the two methods would support lean on the aspects where it has been considered weak i.e. the life-cycle view and awareness of environmental risks (Table 1). The polluter pays principle (PPP), also known as extended producer responsibility (EPR), emphasizes that the summation of all environmental costs throughout the life cycle of any product should be reflected in the market price of that product (Roosen *et al.*, 2013). This would mean that manufacturers would absorb greater responsibility in cleaning, storing, recycling, and reuse of produced waste that leads to national policy formulation, and hence to include the environmental waste into lean thinking.

Table 1 Lean Efforts & Their Affects

Sr. No.	'Envi-lean' efforts	After affects
1.	Less scrap, fewer defects and less spoilage	Reduced environmental waste
2.	Fewer defects, no over-production and simpler & right-sized products	Reduced use of raw materials
3.	Less storage and no inventory space needed	Reduced material, land & energy use
4.	No over-production, no lighting/heating/cooling, no extra space and no over-sized equipment	Less energy use
5.	No over-processing and more efficient transport & movement	Lower emissions

Authors have presented lean manufacturing strategy in a structured sense, and an attempt has been made in this paper to categorize the literature along-with leading conceptual and research methodological dimensions to trim down the wastes & loss of economy to enterprises, by integrating the environmentally-lean (envi-lean) model. This paper reviews the literature of last twenty years (starting from 1995 to 2015), as economic reforms were initiated in the nineties in India, and TPS was identified as lean also in the 1990s; now we want to assess its development, implementation and affects after twenty years. Section 1 of this review provides the comprehensive background of 'lean production and environment' detailing the emergence of the theme and the need to integrate envi-lean; Section 2 is the review methodology with grouping of previous studies, findings, philosophies, core principles and characteristics of the subject along with justification. Section 3 includes classification of articles gathered for this study detailed in preceding chapter with a view to generate common perspective and opinion; while Section 4 discusses the findings from review so as to compare and contrast the issues while also recognizing suggestions to develop 'envi-lean' environment in an enterprise; finally, Section 5 is the conclusion part of the review. Further, an Appendix- I is also given at the end of this paper to list down the details of all the reviewed articles.

2. REVIEW METHODOLOGY

Literature review is a research methodology and the content analysis of historical papers/literature has been applied in this paper so as to create the replicable and valid implications from contents for their use (Krippendorff, 2004). Content analysis is a scientific method for briefing, quantitative analysis of messages, many words of text into fewer content groupings based on explicit coding rules (GAO, 1996 and Weber, 1990); whereas, Holsti (1969) defines content analysis as ‘a technique for building inferences by objectively and scientifically identifying specific characteristics of messages’. Thus, content analysis is a research tool that determines the presence of certain words or theories within texts or a set of texts. In this paper, the target population is the published articles on various databases, followed by the sampling procedure.

In order to facilitate a clear ‘line-of-sight’ from information basis and comprehensive overview of the previous research findings, methodologies/reviews of lean production along with environmental concerns, a sample size of about 110 articles has been taken followed by the deductive approach in selecting and evaluating the body of literature on ‘envi-lean’. The search for publications within defined boundaries has been executed on the scientific databases like Google scholar, Web of Science, Open access journals, Scopus and Online journal search engine; by

searching the article title, abstract fields and keywords; and then limited by certain criteria such as the year of publication, subject areas, document type. The databases search offered numerous publications, which has been reduced to 110 after applying the limiting criteria.

2.1 Coding and Categorization

Categorization of the content is very important in content analysis, which is defined by Sarantakos (2005) as a set of criteria or standard that is incorporated about a theme or value. Categories used in the content analysis are supposed to be very clear and should enable other researchers to have identical outcomes while re-examining the same data with defined categories (Fraenkel and Wallen, 2005). The categories in this paper are determined by probing the literature, reviews and researches regarding the ‘lean production and green’ concept. After accumulating the research topic categories from the study of Burgess *et al.* (2006), a codebook has been developed to employ as a coding instrument, where codebook is an instrument that includes all of the operational definitions of variables (Neuendorf, 2002). All the selected articles were further integrated into the defined framework of four categories of variables i.e. descriptive features, definitional issues, theoretical concerns and research approaches for the conceptualization and methodological analysis (Table 2).

Table 2 Literature Review Classification Framework

No.	Grouping	Content covered	Basis
1.	Descriptive features	Title, country, industry, year, sector, journal	Express the features of sample articles.
2.	Definitional issues	Approaches, conceptual framing, constructs, discipline, process	Discover stability or variation in ‘envi-lean’ definitions to various dimensions. Classify the area that researchers argue falls in lean production.
3.	Theoretical concerns	Purpose, strategy, range, application, function	Establish the range of theories used to enlighten lean and their applications.
4.	Research approaches	Modeling, research methods, hypothesis, case study	Determine the assumptions and research methods used to define lean’.

Reference: Burgess, Singh and Koroglu (2006).

Particularly, the grouping 1 provides an examination of the sample articles/theories expressing its features & trends in the literature like title, year of publication, industry/sector to which the study is applied; grouping 2 discovers the area of supply chains covered by researchers from a range of perspective using either new or existing organizing designs, processes employed; while grouping 3 also illuminates the literature dealing with the issues more or less related to the theoretical bases such as strategies applied or the purpose of study, application of research & its scope; finally, grouping 4 examines the issues associated with research methodology and assumptions used, hypothesis, modelling.

2.2 Validity and Reliability

Validity may be stated as the degree to which a measuring method represents the intentional, or it is the quality of research results that directs us to suppose them as realistic, and the external validity is associated to whether the sample of study corresponds to the population or not (Neuendorf, 2002 and Krippendorff, 2004). In this paper, all the population i.e. articles integrating lean with the environmental concept and in the context of diverse

continents is included and hence, the external validity is assured. Then face validity is confirmed that whether the instrument measures exactly what it is planned to assess or not, and agrees with the results if reasonable (Neuendorf, 2002 and Krippendorff, 2004). The category table has been checked by the experts, researchers whether it is sufficient to assess the intended figures, and content validity is controlled. An instrument has content validity if it covers all aspects of the subject which it is intended to assess, and hence the defined categories’ content validity has been checked by an academician.

Weber (1990) confirms that the categorization procedure must be reliable to make valid inferences from the wording and the reliability issues occur due to the ambiguity of word meanings or category definitions. It is also required to measure the intercoder reliability of content analysis i.e. the amount of concurrence among two or more coders, and a reliability subsample must be assessed randomly to assess it (Lombard *et al.*, 2002; Neuendorf, 2002). Then, coders have to code the documents as indicated in the categories, and also the level of agreement between them needs to be measured. Some measurement techniques for intercoder

reliability are Percent agreement, Scott's pi, Holsti's method, Krippendorff's alpha and Cohen's kappa (Uysal and Madenoglu, 2015). Percent agreement method has been used in this paper to measure the intercoder reliability, by simply adding up the coded cases in same way by the three raters and dividing by the total number. Finally, the intercoder reliability obtained in this paper is 83%, and thus the data can be deemed as reliable.

3. ANALYSIS

The selected articles were integrated into a framework based on various dimensions and classified into four discrete, yet rationally ordered, groupings initiating with least complex perceptions and advanced research issues, and categorized in the following way:

3.1 Grouping 1: Descriptive Features

The review shows that over hundred journals covering diverse disciplines were captured, and the International journal of production economics (10); Journals of manufacturing systems, technology & management (9); Journal of industrial engineering & management (6); Journal of cleaner production (5); international journal lean thinking (3); and the International conferences on lean production, management & industrial engineering (18), accounted for 47% of the total articles, and among which about 78% studies having special emphasis on envi-lean; whereas the remaining literature appears to be focused in another part of lean like productivity & quality improvement, setup time reduction, sustainability issues etc. and based on these

explanatory feature the reviewed studies are categorized as below:

Keitany and Riwo (2014) explored the inventory management through lean tools, and employed the descriptive research design tool for improving the management approach & participation of all employees; Baines *et al.* (2006) studied the application of environmentally & socially sensitive practices to reduce the negative impact of manufacturing activities and harmonizing the pursuit of economic benefits; Taubitz (2010) stated that safety & health are the fundamental to sustainable growth but green-lean can result in improved organizational performance & customer experience; Marvel and Standridge (2009) presented an improved lean process using simulation modelling and experimentation prior to execution; Arlbjørn and Freytag (2013) examined lean in academic literature of 105 international peer-reviewed journals and concluded that only 1/3 of them apply a toolbox view on lean; Castro *et al.* (2012) reviewed the agile and lean manufacturing concepts along with the information & commutation technological solutions, to resolve the issues in manufacturing sector; Dakov and Novkov (2007) concluded that lean principles leads enterprises towards a more sustainable processes & product development; Romvall *et al.* (2010) indicated that lean & green are the favorable options for environmental sustainability within production system in Sweden; and Nordhaus (1995) analyzed the role of climate in economic development, its relationship and the prospects for economic impacts. **Figure 2** categorizes the percentage of the reviewed studies with respect to their year of publishing, and the graph shows that 70% studies are published in last five years (2010 - 2014).

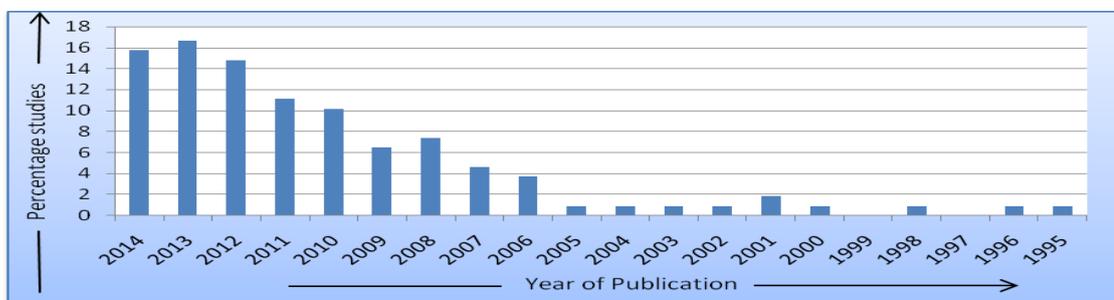


Figure 2 Classification for Year-wise Studies

Improving the environmental performance also leads to reducing costs, increase competitiveness and to be more innovative across the value chain; Maia *et al.* (2013) discussed lean production in textile industry that fosters a sustainable work environment; Chen and Meng (2010) reviewed the course from mass to lean production and issues in Chinese enterprises; Kurdve *et al.* (2014) focussed on integration of environmental and operations management in two global Swedish companies; Moreira *et al.* (2010) presented the role of lean for achieving better environmental performance and an emergent business model for supporting eco-efficiency by literature review; Johansson and Sundin (2014) compared lean product development (LPD) and

green product development (GPD) concepts through a systematic literature review including 102 journal publications; Holweg (2007) presented the research that led to the formulation and dissemination of the most influential manufacturing paradigms of recent times; while, Ogunbiyi *et al.* (2013) strained on lean and sustainability reflecting how it impacts on sustainable construction through literature. **Figure 3** categorizes the percentage of the reviewed studies with respect to the country/continent, and the graph shows that more than 70% studies are carried out by European & Asian authors.

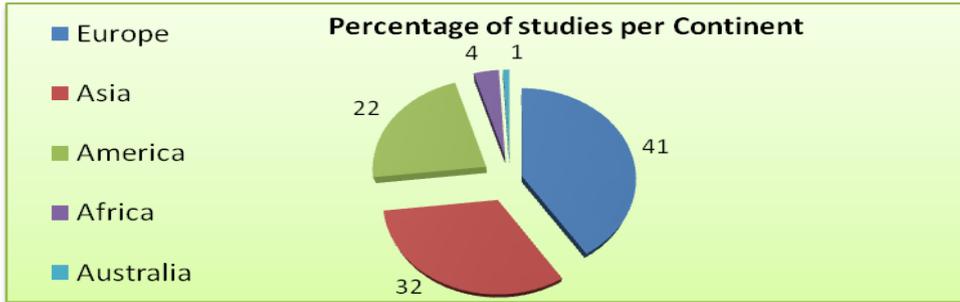


Figure 3 Classification for Continent-wise Studies

Elmoselhy (2013) showed that hybridizing the lean & agile systems together is technically valid to be implemented in an industrial setting; Yang *et al.* (2013) presented a multi-objective line-cell conversion model of traditional conveyor assembly line for reducing workers

& increasing productivity. Figure 4 categorizes the percentage of reviewed studies with respect to the sector/area, and the graph shows that most of the studies have been conducted in manufacturing, automotive, agri-food, transportation & storage sector.

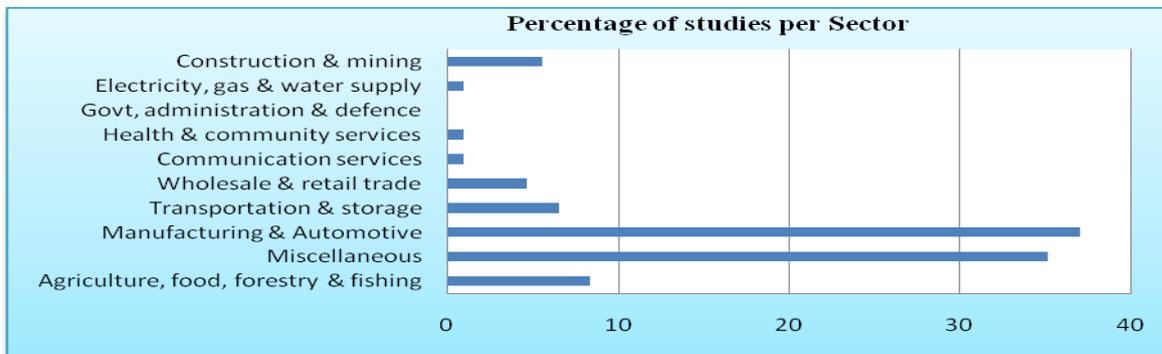


Figure 4 Classification for Sector-wise Studies

Latha and Inbasekaran (2014) explored a framework of new business model for the tanning sector to minimize the environmental impact of manufacturing processes and products; Helldal *et al.* (31) investigated how lean and environmental aspects affect one another and how they could be integrated into a single model; though, Hidy *et al.* (2011) presented a comprehensive discussion of hazards associated with disposal of used or waste electronics & electrical equipment that can be recycled or reused.

3.2 Grouping 2: Definitional Issues

There appears a little compromise on various lean production definitions with either a broad view that are perceptible and further classified in this review. A more precise investigation of the relationships in ‘envi-lean’ definitions exposed that about 55% of the articles have surrounded within the definitions, key concepts concerning the flow of information and material across associations. Out of the articles, two definitions are proposed by Kurdve (2011); two theories by Marudhamuthul *et al.* (2011); two definitions by Prasad and Sharma (2014); and two ideas by Puvanasvaran (2012), where all are concerning the green manufacturing and lean principles, their implementation, barriers and key success factors. A conceptual framework is also developed to classify these reviews which show that about 70% of the articles framed lean as a continuous success practice, 14% as a system and mostly assumed lean itself as a green activity in the view of an enterprise, and

based on definitional issues the reviewed studies are categorized as:

Lean manufacturing, lean enterprise or lean production, is a systemic method for the elimination of waste (Muda), waste created through over-processing or overburden (Muri) and waste created through uneven processes/workloads (Mura) within a manufacturing process (Wikipedia). Lean, a management philosophy derived from TPS (identified as lean in the 1990s) is centered on making evident what adds value to the end product by reducing everything else (Womack and Daniel, 1990; Holweg, 2007), whereas, TPS is known for its focus on the reduction of original Toyota *seven wastes* for improving the overall customer value, but still there are varying perceptions on how this can be best achieved. Henry Ford, one of the first people to who developed the philosophy behind lean manufacturing through ‘continuous flow’ concept on the assembly line of an automobile, where he kept the production standards extremely tight, and this resulted in reduced waste; Gustashaw and Hall (2008) conferred lean & environmental sustainability and broaden the operational considerations from internal efficiency to their effects on external processes; Laird (2012) stated that eliminating energy waste is equally important to industries as a result of rising energy costs; Post and Slaughter (2000) supposed that lean’s reduction of inventories & workers makes it vulnerable and hence the need to replace capitalism with democratic socialism; Puvanasvaran *et al.* (2012) argued that ISO 14001 standards and lean principles can achieve the continual improvement ideas; Chahal (2012) focussed on

producing high quality products along with flexible manufacturing that help businesses remain competitive & sustainable over long term; Bashkite and Karaulova (2012) proposed methodology to facilitate the understanding of TRIZ (Theory of inventive problems-solving) that present the integration model by developing the matrix for contradiction solving of green-lean.

Whitman *et al.* (2008) presented the existing simulation based virtual factory and the application of modern production systems along with the integration of sustainability; Florida (1996) examined the link between advanced production & environmentally conscious manufacturing via survey, phone interviews and field research. Pauline (2009) studied the assumption that lean means green because of doing more with less, yet the evidence to support this is mostly anecdotal and the causal link is unproven; Thackeray (2008) expressed that the approach to eliminate waste, reduce cost and improve process has always been a part of what we can now call 'lean green thinking'; Rakshit and Rodrigues (2013) provided a broad perspective on combining lean with environmental sustainability to assist foundries in remaining competitive; Kyrö *et al.* (2011) illustrated the similarities between lean & energy management and observed that the policies & practices bear a clear resemblance to lean principles (Figure 5); Handa *et al.* (2012) highlighted the interlinks between environmental issues & manufacturing strategies in enhancing eco-efficiency of manufacturing system and successful implementation beyond small standalone initiatives; Harrington *et al.* (2005) investigated the factors leading to total quality environmental management driven mostly by supply-side & demand-side factors that originate internally within the firm; Dües *et al.* (2013) explored that the implementation of green practices in turn also has a positive influence on existing lean business practices; Ioppolo *et al.* (2014) presented the preliminary remarks for possible assessment of key factors related to their integration in envi-lean management; Jadhav *et al.* (2013) explored green lean practices that assist in designing the structurally robust implementation strategies; Kidwell (2006) stated that environmental concerns are a part of the lean concept and air/water emission, generation of solid waste, etc. represents the waste of production; Li *et al.* (2011) elaborated the concept of lean design, its application fields and indicated that it is the only way to establish lean enterprise that make comprehensive lean design.

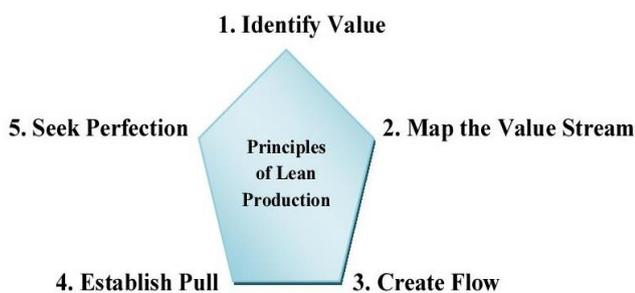


Figure 5 Principles of Lean Production

Carvalho and Machado (2011) explored the possibility to merge lean, agile, resilient and green ideas in supply chain management, where lean-supply-chains seeks waste reduction, agile supply chain (SC) directs rapid-react to

market changes, resilient SC responds efficiently to disturbances and the green SC cuts environmental impacts; Demeter and Matysz (2011) concentrated on how various contingency factors influence the inventory turnover of lean manufacturers through cluster & correlation analysis; Mcleod (2009) proposed an introductory course for students so as to familiarize with prominent operations Management strategies. Treville and Antonakis (2006) concluded that lean job design may cause worker intrinsic motivation, however, there may be substantial differences in intrinsic motivation under differing lean production configurations; Shah and Ward (2007) clarified the semantic confusion of lean production by an extensive literature review using historical evolutionary perspective; Robert (2008) offered ideas on making lean-to-green work framed by firm's management systems & business excellence programs driven by continual improvement; Bose and Sinha (2012) investigated the labor impact of lean production to bring high-trust labor relations including labor development alongside economic growth; Sujatha and Basu (2013) concluded that the implementation of environment management system could be conducted in a structured manner by collaborating human resource factors; Puvanasvaran *et al.* (2012) examined the linkage of lean with ISO 14001 through quantitative research method and questionnaire survey; Prasad and Sharma (2014) concluded that the lean & green can be integrated and offered simultaneously in the operation management to reduce waste & pollution; Prasad and Sharma (2014) cleared that lean is a powerful tool and it can create superior financial & operational outcomes.

3.3 Grouping 3: Theoretical Concerns

Popper *et al.* believed that the theory development is a crucial constraint for the development of any ground; however, some researchers propose that theories should be built upon existing ones. To comprehend lean production, the articles were analyzed to ascertain whether the theories existed or new ones. Comprehensive list of reviews with existing theories were offered in diverse aspects such as economics, application, information, strategic management, sustainability, sociology, functions, and based on these theoretical concerns the reviewed studies are categorized as below:

King (2007) engaged with the transaction cost analysis to hypothesize how collaboration between corporations & environmental stakeholder groups can be structured; Marudhamuthul and Krishnaswamy (2011) addressed the development of green setting through lean principles in an Indian garment export industry to explore their link; Singh *et al.* (2010) provided an efficient lean measurement method on various leanness parameters and fuzzy set theory to remove the bias of human judgment & defuzzification; Nulkar (2014) explored the incidence of environmental performance within various stages of the product life cycle and recommended that there is potential for improvement in Indian SMEs; Jacobs *et al.* (2010) analyzed the shareholder value effects of environmental performance and market reaction to corporate environmental initiatives, awards & certifications; Herrmann *et al.* (2008) presented an analysis of the coherences and interdependencies between lean production & ecologically oriented variables, specifically

energy consumption; ElMaraghy and Deif (2014) proposed a dynamic system approach to investigate the challenges of implementing production leveling & associated costs through a lean cell model and the choice between the 'best lean' & 'no lean' policies; Torielli (2010) provided view on combining lean methods with environmental sustainability for foundries in remaining competitive; Yang *et al.* (2011) explored the conflict between lean practices, environmental management and business performance outcomes from 309 multinational companies (MNC) through AMOS; Pampanelli *et al.* (2011) proposed a model integrating 'envi-lean' through Kaizen approach in an MNC capable of reducing 30% material usage, waste generation and annually cost savings of 132 GBP in one operational cell of GKN driveline, America (**Figure 6**); and Wiengarten and Pagell (2012) investigated the importance of quality Management for environmental initiatives through survey.

Dhingra *et al.* (2012) supposed that growing energy demand has led to increased global energy production with consequential increase in global warming emissions of CO₂ increased by 5.3% in 2010 to a record 30.4 giga tonnes; Netland and Aspelund (2014) reviewed the key dimensions to explain multi-plant improvement programme results in adopting, acting or avoiding of practices in subsidiaries; Bergmiller and McCright (2009) yielded the similarities between lean & green theoretical models to develop a comprehensive integrated model; Duarte and Cruz-Machado (2013) examined how diverse business models and frameworks can add value to modelling a lean and green approach; Huang *et al.* (2009) examined the insights experienced in developing prototype solutions and the schemes for deploying smart objects in manufacturing to achieve real-time traceability & visibility while minimizing the total cost; Ghosh (2012) examined the current state of lean adoption in Indian manufacturing plants and its impact on operational performance; Ramirez *et al.* (2014) identified the factors of environmentally-sustainable aids in firms' processes and charted the strategies to beat supplier barriers; Olhager and Parjago (2012) studied 216 Australian automotive firms and found clear difference of improvement initiatives between make-to-order & make-to-stock firms; Fore and Mbohwa (2010) illustrated the application of cleaner production in foundries in lower income country that impact negatively on the environment leading to unsustainable resource utilization, depletion and pollution; Miller *et al.* (2010) presented a case study of RCELL projects to avoid over production or under production & unnecessary energy use; Anand and Kodali (2008) aimed at selecting lean as a strategy & preference ranking organization method for enrichment evaluations (PROMETHEE) to analyze its impact on stakeholders, through case studies in SMEs.

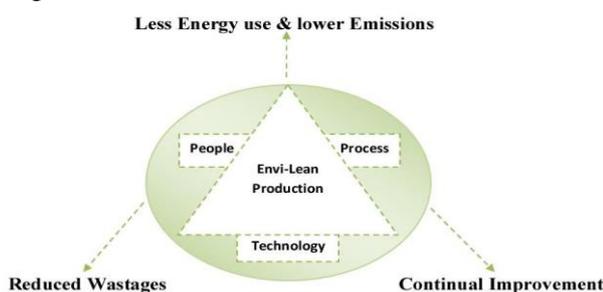


Figure 6 Environmentally-Lean Production

Sawhney (2007) proposed a methodology to clear the link between lean ethics and their ecological impacts through case study in metal cutting industry; Maxwell *et al.* (1998) covered the organizational decisions to balance productivity & quality goals along with environmental responsibility by case studies at two units of Honda; Rosenbaum *et al.* (2012) studied the 'green-lean' application in the construction of a hospital to discover environmental or productive waste sources; Galeazzo *et al.* (2014) argued on execution of green-operation management based on collaboration & interaction; Silva *et al.* (2013) studied the green-lean correlation using concept mapping mode in relation to a positive effect on resources & energy consumption.

3.4 Grouping 4: Research Approaches

Studies can be tested using the profile and form of the subsequent knowledge generated assuming scientific method, empiricism, views, phenomena, relationships, and modernism. For this particular parameter, the framework consisting functionalism as well as the fundamental humanism and structuralism was employed, and based on these research approaches the reviewed studies are categorized as below:

Liu *et al.* (2014) developed a non-dominant sorting genetic algorithm to attain Pareto front and to diminish total non-processing electricity consumption as well as the total weighted delay in a job shop; Ahemad *et al.* (2013) highlighted the weak areas as potential for company to improve green manufacturing execution through case study in Indian steel industry; Elsayed *et al.* (2013) discussed a 3-step approach for proactive performance assessment of green-lean through case study in an automotive, resulting 10.8% drop in production cost; Salleh *et al.* (2012) studied the green lean total quality information management system via questionnaire in 30 automotive vendors in Malaysia; Esmer *et al.* (2010) intended to find out the optimal number of handling equipment & reduced the ecological harm of Turkish container terminal via a simulation model; Abdulmalek and Rajgopal (2007) applied the value stream mapping (VSM) & simulation model to contrast the before & after state in an integrated steel mill; Purvis *et al.* (2014) explored the flexibility in context of lean, agile & leagile supply networks and investigated the vendor & sourcing flexibility in two UK based specialist fashion retailers; Vivek and Ravindran (2008) emphasized the impact of environmental uncertainty on the lean practices followed by small manufacturing firms; Satao *et al.* (2012) reviewed on how green manufacturing can be achieved through lean in order to prevent pollution & protect environment.

Roosen and Pons (2013) offered a method to integrate environmental waste into lean through VSM in manufacturing setting for carbon footprint; Omer (2008) reviewed the literature on energy sources, environment & sustainable development for reducing fossil energy use and to promote the green energies in construction sector; Venkat and Wakeland (2006) investigated the environmental performance for CO₂ emissions using simulation model and suggested that it is quite possible for lean & green to be in clash that leads to tradeoffs and further chances for optimization; Hibadullah *et al.* (2013) explored the relationship between lean and environmental performance in

Malaysian automotive industry by structural equation modelling (SEM); Yang *et al.* (2010) hypothesized that environmental management is partially an extension of advanced manufacturing practices and found that the electronic & electrical industries in China & Taiwan have developed their own practices; Herron and Hicks (2008) disseminated the selected lean techniques in companies of

north-east England to improve productivity and obtained the savings as eight times greater than total costs from 15 companies; Khalid (2011) suggested the motion study to achieve company goals and ARENA software to simulate the inspection lanes at Motor Vehicle Periodic Inspection station and yielded an expected improvement of 174.8% in production capacity.

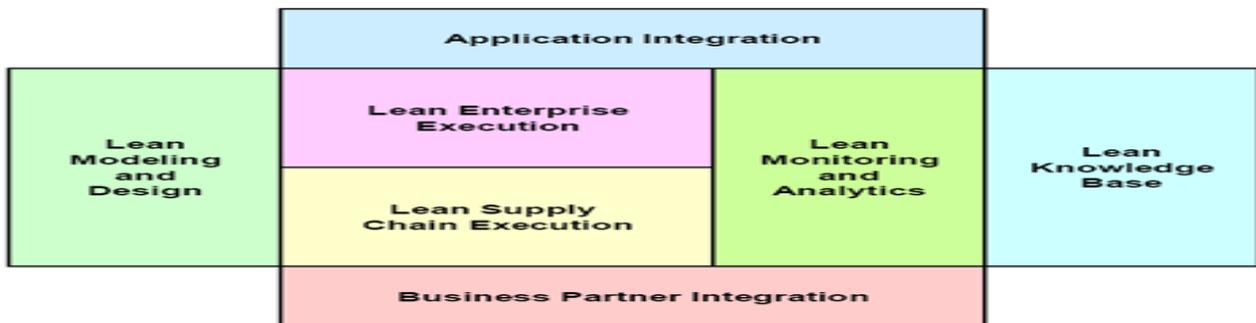


Figure 7 Lean Production Framework

Kurdve *et al.* (2011) dealt with the environmental value stream mapping for achieving better results in two case studies at Volvo; Nasab *et al.* (2013) introduced an integrated dynamic approach to investigate the technology effectiveness of lean manufacturing in enterprises and ability to alter the parameter's affects on others; Venkataramana *et al.* (2014) aimed at lean implementation in an Indian automotive industry through multi-criteria decision making model & analytical hierarchy process to create product mix flexibility; Marudhamuthu *et al.* (2011) addressed the lean implementation in an Indian garment export industry by VSM and single minute exchange of die (SMED) approaches which resulted in reduced set up time; Mittal and Sangwan (2014) developed a model for environmentally conscious manufacturing by SPSS tool, exploratory & confirmatory factor analysis and SEM to validate the model; Taggart and Kienhöfer (2013) concluded that lean audits are only effective ways to measure improvements in operational performance and tested it in 64 manufacturing sites; Sullivan *et al.* (2002) provided a roadmap for the analysis of equipment replacement decision problems through VSM; Wang *et al.* (2008) introduced a step-by-step implementation framework for lean production & product development by means of marketing research on product development & design processes (Figure 7); Upadhye *et al.* (2014) tried to find out the implementation enablers of lean tools i.e. Just-in-Time in the Indian corrugated packaging industry through interpretive structural modeling; Jaganathan (2014) carried out the assembly line balancing & layout modification in a garment industry using largest candidate algorithm rule, and increased the efficiency up to 26% & the productivity by 25%.

Finally, current trends in lean production research incorporate the development of productivity & quality improvement processes within environmental boundaries; on the other hand, sustainability, integrated manufacturing, deployment of information technology to reduce manufacturing lead time, and human health issues have also been placed on priority by authors.

4. DISCUSSION

Based on the findings of the review, it is possible to discuss the issues like how to conceptualize and develop the field and evaluate the impact of the various trends in lean production research. The review also indicates that many other sectors like government, health services, construction, communication and industrial markets do not yet appear to have researched comprehensively. Apart from this, some findings of the review are as:

- a) Despite of the process approach, lean production primarily focuses at reducing the risk of sub-optimization and the production part of the lifecycle; thus, the associations working with lean have the possibility of costs sub-optimization from a life-cycle viewpoint.
- b) Lean along with green concept improves the process flow & employee morale, and also lowers the regulatory non-compliance risk. Adopting green practices are not only good for sustainability but are also good for business value.
- c) There is a need to include environmental waste along with other lean wastes where focused waste management requires shop floor people, engineers, and management to know what & where the waste is being generated.
- d) Lean can be leveraged to create even more improvement by addressing the environmental 'blind spots' as they are often suppressed in overhead & facility support costs.
- e) The environmental & human health risks are often not explicitly considered in lean initiatives that can affect customers & stakeholders throughout the product life cycle.
- f) The more difficult problem to overcome waste is the lack of vertical integration between the organizational data on environmental waste and the processes that created the waste.

5. CONCLUSION

After the comprehensive literature assessment, it is concluded that the human health & environmental issues,

improved product quality and the associated economic benefits in sustainable production systems can be achieved through lean principles that eliminate uncertainties in processes, reduce wastes and non-value adding activities; and integrated product development and manufacturing processes along with the interoperability of information systems can enhance the business value in production systems.

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APPENDIX- I

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