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A Lean-Green-Agile and Resilient Combination Towards Sustainable Manufacturing- A Review

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Abstract- The modern manufacturing operations are always towards sustainable production through sustainable operations. Lean Manufacturing is one of the leading liner to increase operational efficiency in manufacturing industry but somewhere lacks to attain sustainable production. It has been observed that when the most common manufacturing paradigm are lean, green, agile, resilient, green and sustainability to attain sustainable production. In order to understand this, a literature study conducted in this research that focuses on the study of previous available literature regarding all these paradigms (lean, agile, resilient, green, and sustainability) and explain their looping among each other. The literature study results that the lean is straightly helpful in reduction of non-value added actives; agile is helpful to manage market demands and volatility among orders; resilience is helpful to handle uncertain disruptions during manufacturing; green is helpful to attain green and environmental friendly production with the alignment of sustainable production through sustainability which is affective in all environmental, economic and social implications. This literature study is highly helpful to understand, manage and clarify all the prominent paradigms of manufacturing on one platform that is a good contribution of academicians and practitioners working in this field.

Keywords- Lean Manufacturing, Agile Manufacturing, Resilient Manufacturing, Green Manufacturing, Sustainable Manufacturing

I. INTRODUCTION

For the reduction of wastes, lean manufacturing is the basic required tool for every competitive industry and for its sustainability, there is a need of a consistent assessment. As there are many advancements in the present time, the mass production is becoming obsolete and the customers are interested in more updated and innovative products. To full fil this need, there is need of flexibility in manufacturing systems [1]. From past few decades, Agility has been chosen as a tool to harbor flexible variations to the demands. The Flexible Manufacturing Systems (FMS) are quite different form Agile Manufacturing (AM) as the Flexible Manufacturing needs longer response time to accommodate the unexpected changes into product variations [2] .There is a need of collaborative operations of various departments in Agile manufacturing rather than the conventional sequential operations. Agile manufacturing concentrate on management of time whereas the flexiblity focuses on measurements of competencies[3, 4]. There has been a need of resilience in management to reduce these effects for longer time whereas maintaining work flow [5]. There may be few disruptions in firm's supply such as natural disasters and criminal attacks etc. [5]. The corporation's incumbency threatened heavily by these disruptions. The disruption can weaken the customer-corporation relationship by creating difficulties in the shipment of finished goods to customers in the specified time. The word Resilience have different meanings, through all these fields the idea for it, is narrowly related to the capability and the ability of a constituent to be reversed to a state in which it was before the disruption –[6]. The environmentally suitable and friendly manufacturing system called as sustainable manufacturing system [7, 8] and the implementation of a green manufacturing system is inevitably becoming an organization's primacy in the selection process of a suppliers input. The problems caused by the global warming and harmful gasses emissions, the green manufacturing has become the great interest of researchers [9]. As the world has been shifting in the direction of renewable resources, the sustainable system is of a great interest, as these do not affect the environmental health. Because of these improvements, the requirements of expensive equipment are being replaced.

In this world of variable conditions, there is nothing that cannot be expected to occur either this is a natural occurrence or any human routine activity. This current work concentrates on the review of leading paradigms

in manufacturing, their interrelation in between and their effect on sustainability. It has been observed that the focus for the optimization of one tool can cause variations in the performance of other tools [10]. Mostly the managers asked to manage these different constraints, as this show sometimes clashes [11]. To compansate these conflits scientists have defiend many ideas and methods, from which the most prominent method are Green-Lean-Agile and Resilience. Due to considerable interest of researchers there were many analysis done on combining between the Lean and Green goals. The researches show about the association of lean manufacturing with sustainability concentrates about the lean manufacturing. On the association between lean manufacturing and GWRT (Green Waste Reduction Total) a research was done to forecast the interdependency effect of one on the other factor and the results proved that application of GWRT has a positive effect on cost-effectiveness [12]. Form studies it found that many manufacturing firms have applied the concept of lean manufacturing for minimizing the wastes that were badly effecting the environment. The responsibility of purchasing and supply management (PSM) should be ensured in regards to the environmental activities of their suppliers which are major responsible to these consequences [13]. The environmental management can be helpful in showing an undiscovered path that may reduce the supply chain cost by more capable usage of natural resources. The advanced manufacturing process are shifting towards sustainable production by utilizing sustainable processes. However, a combinational effect of lean, green, agile and resilience (rather lean and green) will definitely help and leads to the objective of this research study to study these paradigms and their effect on the sustainability. Due to these important up-gradations, the need of costly equipment are being substituted. As the condition of our world are very much variable, there is nothing which can or cannot be expected to happen either by the nature itself or by the action of human being. In this present work, the main concentration was the review of leading paradigm regarding manufacturing sector, their correlation and effects of these paradigms on sustainability. This has been studied that the optimizing effect of one tool can be resulted in the variation of performance of other one [9]. Mostly due to the clashes of these different constraints the managers are asked to manage these [10]. Scientists are striving and defining many ideas and methodologies to compensate these conflicts, one of these techniques is Green-Lean-Agile and Resilience that is a most noticeable methodology. As the scientists have a significant level of interest in this area, there are many analytical studies made on the combination of Lean and Green goals. Many researches have shown about the combination of lean manufacturing with sustainability focuses on lean manufacturing. From the literature, it studied that many manufacturing organizations had utilized the lean manufacturing concept in order to minimize the environmental damaging wastes. There should be assurance regarding the responsibility of purchasing and supply management (PSM) regarding the environmental effects of their suppliers' activities that are generally main responsible of these consequences [12]. The role of environmental management cannot be neglected in this regard as this can much helpful in discovering any hidden path that may result in cost reduction of supply chain by enabling more effective utilization of naturel resources. There are many advanced types of manufacturing processes which are moving towards the sustainability by using sustainable process. Though it is hoped that the combining effect of lean, green agile and resilience (instead of lean and green) will surely assist and leads towards the objective of this current research study to analyze these paradigms and subsequently their effects on sustainability. Based on this, the remainder of the paper is structured, as section 2, 3 and 4 are methodology, results and discussion and conclusion sections.

II. METHODOLOGY

This present work aimed to study the combined effect of lean, agile, resilient and green techniques in combination. These all practices, when implemented individually or in combination, transfer the lean implementation to the sustainability. Due to this reason, a literature review was required to be conducted by utilizing the electronic database that was recommended by the best researchers of this filed [14-19]. The fundamental source of data for this publication was the material collected from previous published works in the perspective of lean, agile, green, resilient and sustainability in combined or in individual form. Next to the combining, a search done to consolidate the studied articles according to constraints and objectives of the research area. Selection of related articles after the successful search of related articles. The essential articles are selected which are required for the implementation of all of the required paradigms (lean, green, resilient, agile and sustainability) in any manufacturing organization. In this type of selection process, the publications were analyzed according to the involvement of paradigms, methodology and application. Moreover, this research concentrate on the explanation of sustainability and the involvement of each paradigm for the progress of the conceptual background. The selected articles were those which were suitable for studying with the scope of manufacturing areas of industries. Different articles were studied which were very much useful in obtaining the core objective of this study. An analysis of the articles was done to fulfill the gap from the literature provided in this work and clarifying the previously published work concentrating on this aim.

The literature study is of very much important for the selection of suitable articles based on their involvements and the summary of the articles utilized are mentioned below.

III. A State of Art Literature Review

A. Lean Manufacturing

Lean Manufacturing has been a promised manufacturing optimization tool in various aspects for more than two decades. Majority of the firms decided to implement the lean in view of the performances and success of lean operated companies. Another name for LM is "Toyota Production System" by Taiichi Ohno and Shigeo Shingo in Toyota [20]. "The machine that changed the world" written by James P. Womack on lean production [21]. Afterwards, In 1990s, there was a boom in the application of lean production throughout the world. Objectives and goals of lean include waste minimization, inventory time and space reduction and quality improvement meeting the customer demands in an economic way. Lean strategy comprises of seven types of waste reduction as well as minimization of work in progress.

The seven wastes include overproduction, over-processing, over waiting, over transportation, over inventory, defects, and over motion. Naylor, et al. [22] define lean to eliminate all the wastes based on time and scheduling. Wastes are the activities which are always towards reduction in non-value added activates. While value is anything, the customer would be willing to pay for. Lean practices has an extensive variety and most common tools are Kanban, 5S, Just-in-time, Kaizan, poka-yoke, virtual stream mapping, SMED etc. Each tool has its own way of implementation and a proper classification strategy is necessary for the availability and implementation. Tool implication raises some issues related to cultural, technical and top management behaviors towards lean. There are some external and internal factors affecting lean implementation like employee's training and education, resources, government interventions etc. Thus, the goal to be achieved is not based on a single department rather on the success of the whole firm. Table 2 further explains about the key notion of lean manufacturing. Table 2 clearly shows the continuous improvement and value focused implementation of lean [23]. Lean finds its applications in various sectors that clearly understood and implemented in a continuous improved way. In a meeting at Carnegie Mellon University, IT management program invited Dr. Paul Smith, a lean practitioner, provided a lecture on lean manufacturing in which he focused on lean thinking. The key for lean is to consider the cultural and process paradigms before the IT management system imports the lean technique.

Table 1: Summary of Methodology

Research material	Research articles and conference papers
Literature review methodology	Literature Review
Period covered	1985–2018
Databases used	Emerald, Science direct (Elsevier), Scopus, Springer, Taylor & Francis online, ISI web of science, IEEE explorer, Scientific.net, Inder-science publishers
Keywords and phrases used to search database	Lean, Lean Manufacturing, Lean tools, Lean Production, Lean literature review, Lean Supply chain management, lean six sigma, Lean and sustainability, Lean manufacturing conceptual framework, Manufacturing System, manufacturing supply chain, waste, Lean thinking, Lean approach. Agile manufacturing, Agility, Agile supply chain management, Flexible Manufacturing, Flexibility, agile manufacturing literature review, agile manufacturing conceptual framework, agile production, agile approach, Resilient supply chains, resilience, resilient supply chain management, Resilience Engineering, resilience manufacturing literature review, resilience manufacturing conceptual framework, Resilient approach, Green supply chain management, green manufacturing, Life Cycle Sustainability Analysis, Environmental management, Supplier development, Supplier management, supplier selection, green supplier, environmentally conscious manufacturing, green manufacturing literature review, green manufacturing conceptual framework, green and sustainable manufacturing, environmental impact, green approach, green operations

Table 2: Previous Literature About Lean Manufacturing

Author Name & Years	Methodology	Research Focused Area	Findings(Authors points of view)
Doolen and Hacker [24]	Literature review/survey	Electronics industry	Lean practices key areas and assessment tools have been reviewed in a survey on electronic industries to develop a tool to apply in any electronic industry to check the level of implementation in each key area of lean.
Baines, et al. [25]	Literature review	Design and product development	Lean adoption in the design and product development involves top management influence, company culture, re-engineering of workflow and many other prospects to deal with. Value addition in this system requires lean specific disciplines and lean orientations.
Bendell [26]	Literature review	Manufacturing industry	A combination and compatibility of six sigma and lean has been reviewed and a connection has been highlighted against various tools and aspects between six sigma and lean organizations.
Langenwalter [27]	Theoretical Model	Multiple Manufacturing industry	Lean manufacturing impacts on sustainability of organizational, environmental and the life performance are discussed. Author's concern to the sustainability is the adoption of lean as a key tool in an organization.
Abdulmalek and Rajgopal [28]	Case study	Steel mill	Authors proposed structured framework for process industries that are least responsive to lean methodologies. A detailed simulation model was presented using value stream mapping with potential outcomes.
Taj [29]	Survey based literature review	Multiple manufacturing industries	Author has made a survey based study on different key areas of lean manufacturing in various Chinese companies and listed them in an assessment tool for ranking the firms based on their contribution to each key area.
Nordin, et al. [30]	Survey	Automotive industry	Based on survey through emails in various aspects like company's product type, size, age etc. Kaizen was found to be the leading tool in companies. Authors pointed out the driving forces for lean implementation in different companies.
Bhamu and Singh Sangwan [31]	Literature review	Automotive industry	Author explains various definitions and review on lean multiple applications of various tools in the manufacturing industry.
Martinez-Jurado and Moyano-Fuentes [32]	Literature review	Manufacturing industry	This study employs lean practices to achieve sustainability in review. Critical factors are highlighted for economic sustainability and the research focuses to correlate the SCM, lean practices and sustainability.

Author Name & Years	Methodology	Research Focused Area	Findings(Authors points of view)
Abobakr and Abdel-Kader [33]	Literature review/Survey	Multiple manufacturing industries	Authors describe model based on survey and review in which they highlight lean tools implementation effects on all sustainable dimensions.
D'Antonio, et al. [34]	Case study	Aeronautics industry	Explains simultaneous implementation of lean and information tools. Data analysis with proper mathematical techniques in correlation with lean implementation, are employed to minimize the tolerances for the grinding of gears.
Garre, et al. [35]	Literature review	Aerospace industry	Five lean tools successfully were employed in predicting non-value activities after implementation in assembly of pressure vessels. Improved layout with 5S and controlled movements are the triggers for the improvement.
Munteanu and Ştefănigă [36]	Survey	Manufacturing industries	Authors explains the lean approach to the manufacturing industries for Romanian bloggers, its success factors and barriers. Statistical approach using six sigma and the JIT tool are used to investigate, in various blogs, about companies interests.
Anvari, et al. [37]	Literature Review		Synergy of Lean Manufacturing and Total Quality Management is required to achieve business excellence.
El-Namrouty [38]	Literature Review	Palestinian Manufacturing Industry	Authors contributed that lean manufacturing techniques help in economic efficiency.

B. Agile Manufacturing

The agility to meet the demands of customers in a minimal time and delivery of products according to the customers' needs has attracted the firms to catch with the growing competition. The term 'Agility' comes with the responsiveness of companies to the market variation [39]. From a business perspective, the term agility is also referred to as flexible manufacturing system. Automation was thought to be the initial concept of flexible manufacturing to change the set-up times, faster delivery etc. but later on it was used as business perspective [40]. Naylor, et al. [22] defines agility as the company should have market knowledge and perform profitably in the variable marketplace. Agile manufacturing is not just a short-term continuous improvement strategy but also a different way of doing business. Agile manufacturing demands the following resources: Innovative organizational workforce, flexible and intelligent technologies and highly skilled human resource [41]. The focus of agile manufacturing is to be responsive on product variety and the customer needs. For many firms the concept of agile and lean manufacturing seems similar but they are very different. Lean is to the strategies utilizing limited resources while agility is to the strategies with abrupt changes [42]. Agility response is both qualitative and quantitative variation in the demands. The period after the World War 2 brought many problems related to customer backlogs in orders and inabilities to supply the needs of customers [43]. That created a situation of preference-based orders of customers due to delay in the delivery and quality degradation [44]. The core competence concept of agile based on company's workforce and product and classified into individual and firm core competencies. Table 3 highlights about key concept of agile manufacturing.

Table 3: Previous Literature about Agile Manufacturing

Author Name & Years	Methodology	Research Focused Area	Findings (Authors points of view)
Cho, et al. [45]	Case study	Electronic laboratory	Agile manufacturing key technologies in some Korean companies are highlighted and proposed in electronics lab of Korean university using product data model and product life cycle assessment.
Christopher and Towill [46]	Conceptual model	Manufacturing industry	A framework on agile manufacturing and logistics is presented employing hybrid strategies of agile with lean using Pareto and de-coupling point analysis.
Gunasekaran, et al. [47]	Case study	Aerospace industry	A thorough study on GECMAe industry is made by the assessment-using framework to analyze the level of agile implementation and guidelines for current and future perspectives.
Brown and Bessant [48]	Case study	Multiple industries	Author used the model employed by Bessant et al (2001) to present 3 automobile and 3 computer assemblers of USA collected from their senior staff members about the agility of their manufacturing techniques that are flexible/capable enough to cope up with the continuously changing demand of customer
Elkins, et al. [2]	Theoretical model	Automotive industry	This paper explains two decision models: spreadsheet model and decision tree model, for buying models based on three unpredicted product change namely dedicated, agile and flexible systems.
Pan and Nagi [49]	Theoretical	Manufacturing industry	A scenario-based heuristic is used to classify the operations and other activities to predict the agile performance in an organization.
Vinodh [50]	Case study	Rotary switches manufacturing industry	Author performs sustainable analysis on the baseline and five proposed CAD models of knob of a rotary switch for the measurement of its environmental impact and propose the most sustainable model on the basis of measured environmental parameters
Inman, et al. [51]	Literature review/Conceptual model/Survey	Manufacturing industry	Author collects the data about the "Just in time" production and purchasing on agile and effect of agile techniques on the performance measures from managers of different companies of USA. He applies the data on the model based on five hypotheses and after calculation presents a perfect agile manufacturing model with standard estimate of hypotheses up to 2 significant figures.

Author Name & Years	Methodology	Research Focused Area	Findings (Authors points of view)
Gunasekaran, et al. [52]	Case study	Multiple industries	This study identifies the importance of business analytics in agile manufacturing through statistical tools on AM enablers. Four companies' performance is observed through a framework where market turbulence is involved in the assessment.
Kisperska-Moron and Swierczek [53]	Case Study	Manufacturing Industry	Authors conclude that agile of organizations is dependent upon the following parameters: • Inter-Business Relationships • Use of IT • Relationships with Competitors
Yang, et al. [54]	Theoretical Study	Manufacturing Industry	The usage of robots and mobile manipulators in agile manufacturing helps speed up the processes and increase the productivity.

Table 3 shows the necessity of agile in order to be among the competitors and various strategies and employee role in the formation of flexible manufacturing. Various manufacturing sectors have been observed to be agile successful upon the fulfillment of key factors. The individual based core competencies consist of one's skills, attitude, knowledge and expertise [41]. These can be upgraded through motivation and proper training of employees. A flexible process layout is also a key success factor besides these as it fulfills the criteria of shortened lead times and quality improvement. A virtual supply chain is information-focused compared to the old inventory-focused. Functions of agile manufacturing include prequalifying for orders among the competitors, which is a success factor too, evaluating product design and manufacturing by capabilities of partners[55].

C. Resilient Manufacturing

After achieving lean and agility, the third paradigm on which most of the manufacturing systems focus is resilience. Resilience considered as the flexibility to withstand risks or disruptions and bringing the system to original or least affected state. With the continuously increasing burden of inventory on the manufacturing systems because of globalization, most of the manufacturing systems now days prefer to adopt the new techniques and reduce the inventory level by taking raw material and delivering products exactly on time. Because of adopting these new techniques, manufacturing systems exposed to both internal and external risks and thus the systems require presence of resilience to compete in the continuously changing trend of market. Internal risks as those which arise from within the system like incorrect information or data, workers inefficiency or quality problems while external risks are those which are not in control of manufacturer like natural disasters, price fluctuations, political and economic conditions [56]. In the whole process of manufacturing starting from intake to the production and then transportation of manufactured items to dealers and customers, the complete supply chain system needs the presence of resilience to behave efficiently. The aptitude and ability of any system to pact with risks and disruptions without affecting quality and quantity of output and quantity of products is considered as resiliency [56]. Flexibility and redundancy are the two necessary properties for making a resilient manufacturing system. Flexibility shows that the system can withstand the changes despite fluctuations or variations in raw materials or manufacturing techniques and redundancy is defined as the presence of surplus suppliers, manufacturing assemblies and transport facilities [57]. Visibility in the context of resilience is to be prepared end-to-end from the demand to the supply [58]. Thus, in order for a company to remain in continuity of operation, these three prospects implemented into the supply chain management. According to Fiksel [59] diversity, efficiency, adaptability and cohesion are the main characteristics of a resilient system. Table 4 highlights about resilient manufacturing.

Table 4 clearly explains about resilience in previous researches. Organizations and their supply chains are interdependent on one another, so the presence of resilience in supply chain is also necessary for the growth of industry. According to Christopher and Peck [60] in order to make a resilient supply chain highest level of collaboration and risk management culture should be developed in the organization. Risk management can be completed in four phases. Risk identification, extent or impact of risk, risk mitigation and monitoring of risk is the sequence vise procedure

Table 4: Previous Literature about Resilient Manufacturing

Author Name & Years	Methodology	Research Focused Area	Findings (Authors points of view)
Christopher and Peck [60]	Theoretical model	Manufacturing industries	Author highlights different types of risks faced in the supply chain and suggests a SCM team for resilient manufacturing system. Authors give the principles and supply chain collaboration system for increasing resilience in manufacturing systems
Hu, et al. [61]	Literature review	Manufacturing Enterprises	Author develops a mathematical model by considering the manufacturing enterprise as a network of nodes to highlight different types of constraints and their effect on the production order resiliency, In this paper cost function is defined in the model and a comparatively balanced redundancy level is developed to cope up with both operational and inventory redundancy
Zhang and Van Luttervelt [62]	Theoretical model	Manufacturing industries	Author has given guidelines necessary to follow for the development of resilient manufacturing system, and shows the improvement in resilience by following these guidelines in examples. The author explains the difference between the engineering resilience and ecological resilience.
Bhamra, et al. [63]	Literature review	Manufacturing industry	Author presents a review on resilient manufacturing in various SMEs and discusses various dimensions of resilience and solutions in a framework.
Demmer, et al. [64]	Case study/literature review	Automotive industry	Authors explain on how the antecedents and strategies of resilient manufacturing can fit into the small and medium sized industries. Besides, drivers for resilience and implementation are discussed.
Saurin and Júnior [65]	Case study	Electric distributor company	This study focuses on electric distributor company and proposed a modified framework presenting relationships between criteria for safety assessment and management practices.
Heinicke [66]	Theoretical Model	Manufacturing industry	This paper explains four different approaches for obtaining resilience, agility and robustness in a production system
Hohenstein, et al. [67]	Literature review	Manufacturing industry	A detailed review on resilience is provided with every dimension and a framework for resilience building for enterprises
Agigi, et al. [68]	Literature review	Grocery manufacturing industry	This study explains the design, redundant and flexible strategies in relation to the risks associated with demand and supply.

Zahiri, et al. [69]	Case study	Pharmaceutical industry	Author introduces five indicators for resilience measurement and then defines the objective and constraint functions in mathematical form. This paper presents an algorithm obtained from the mathematical calculations and then apply this on pharmaceutical industry
Simba, et al. [56]	Survey	Grocery manufacturer	The author performs a thematic analysis of data collected through interviews from 12 firms and provides verification of supply chain risk management practices across grocery manufacturers. Authors point out the increase in resilience despite disruptions, by the implementation of supply chain risk management
Peck [70]	Case Study/Survey	Aerospace Industry Supply Chains	There is scarcity of understanding supply chain, which should be considered keeping multiple perspectives of value stream, asset, organizational networks and social environment in mind.
Yao, et al. [71]	Mathematical Model/Literature Review	Manufacturing Industry	The presented a model of an enterprise that captures production, demand, capacity, and changeover limits, and costs.

for handling different types of disruptions occurring in the path of resilience in supply chain. Different types of models have been presented by researchers for making a resilient manufacturing system. Hu, et al. [61] gave a mathematical model by representing manufacturing enterprises as a network of nodes. Hoffmann, et al. [72] addressed the core issues of geometric interoperability and highlighted the importance of resilience in model-based engineering.

D. Green Manufacturing

Green Manufacturing has captured global attention in this era of global warming and climate susceptible to hazardous pollutants. Environment related issues and protection are now becoming vital necessities for a strategic manufacturing system [73]. Various companies, which cause major roles in environmental issues, of different sectors of the European countries are now taking steps to green their manufacturing processes and the executives consider environmental protection as first priority besides lower costs and lead times and quality improvements [74]. The only way to adapt the strategic and operational processing to environmental safety is through the green supply chain. All the stages in supply chain play their role in environmental degradation, from supplier through the process/product to the disposal or recycling [75]. Many companies have been aware of the environmental risks and green manufacturing; however, they could not be able to implement green approach due to the non-availability of suitable analytical tools and procedures. However, after the introduction of ISO 14000, many companies found green manufacturing resourceful based on environmental management system policies, some still face the problems of sustainable operations. Environmental management evolution found its focus in many companies as a key area to be competitive in the global challenge [76]. Some government and agencies in various countries have developed rules and restrictions on the machining processes to be eco-efficient [77]. The automotive industry makes a major role in environmental risks and some top ranked automotive companies like FIAT, Volkswagen and BMW have already set up their recycling processes [78]. Table 5 explains about green manufacturing in view of previous literature available. Table 5 highlights green manufacturing related aspects and its impact on environmental health improvement. The introduction of environmental management system has major impact on the operational strategy in different ways like Product planning, procurement policies and logistics. Green manufacturing has different strategies for processes and products. The role of green manufacturing for processes is to conserve energy and resources while minimizing production of toxic

Table 5: Previous Literature about Green Manufacturing

Author Name & Years	Methodology	Research Focused Area	Findings (Authors points of view)
Azzone and Noci [81]	Case study	Multiple industries	Author highlighted the environmental performance measurement systems for green implementation in automotive and chemical industries. The framework provides the opportunity for firms whether they switch to pro-active strategy keeping in mind the economic parameter
Tan, et al. [82]	Case study	Manufacturing industry/gear	A decision-making framework in the selection of cutting fluid is discussed along with a case study keeping the cost, environmental impacts, and quality in the subject.
He, et al. [83]	Case study/ conceptual model	Manufacturing industry/gear	A process planning support system for green manufacturing has been developed to optimize the resource consumption and environmental impacts using model repositories and databases of green attributes. This helps the companies to find their contribution and adaptation to greening processes.
Zhu, et al. [84]	Survey	Multiple Industries	Explains the implementation of green supply chain management and performance prediction with focus on quality and JIT using analysis of variance tool. Varying results of implementation and performance includes factors such as foreign countries' pressure for climatic restrictions, strive for improved management etc.
Hong, et al. [85]	Survey	Manufacturing industry	Authors explain the implementation of strategic green orientation in coordination with IPD, SCC, GPO and BUP. A framework is designed to evaluate BUP, SCC, GPO and IPD based on the empirical implementation of SGO
Ninlawan, et al. [86]	Survey/ Case study	Electronics industry	Authors highlighted green supply chain components based on green related techniques, certifications, distributions etc. Reverse logistics based on 3Rs (reduce, recycle and reuse) and alternatives of landfill are proposed
Nunes and Bennett [87]	Case study	Automotive industry	Authors took the databases from top three car manufacturers and observed various green aspects including green building, green supply chain, green eco-design and some other factors in these companies.
Shang, et al. [88]	Literature review/ survey	Electronics industry	Firms are categorized into green supply chain groups based on a factor and cluster analysis in view of the green supply chain management dimensions.

Dornfeld, et al. [89]	Theoretical Model	Manufacturing industry	This study includes green manufacturing need for today, distinction with sustainability, drivers and restrictions on green manufacturing. Besides, practices on various organizations and strategies are highlighted as well.
Chuang and Yang [90]	Conceptual model/survey/case study	Manufacturing industry	Authors presented a three-layer model in which they collected data from three companies and categorized the dimensions, strategic subjects and assessment factors via an analytic network process through questionnaires.
Kaur, et al. [91]	Case study	Manufacturing industry	Author categorizes the 36 shortlisted barriers that are affecting implementation of green supply chain management technique into 6 groups using DEMATEL approach and then suggests improvements in the system in overcoming with these barriers.
Deif [77]	Conceptual Model/ Case Study	Wood Products Manufacturer	The author developed an architecture that provides guidelines for greening the manufacturing system, the steps are given as follows: • Determining current green level • Developing a green manufacturing plan • Implementation • Sustainability
Paul, et al. [92]	Literature Review	Manufacturing industry	The authors deduce that using environment friendly fuels, organizations acquire a green image and competitive advantage that increases industrial performance.

substances and wastes, but for products, green plays a role in minimizing negative environmental impacts throughout the cycle time of products[79].

In many companies, the criteria for 'good' or 'bad' supply chain process predicted based on environmental impact. However, transition towards the modern green supply chain demands management policies on managerial level. The executives of firms from all over the world agreed upon to cut down the use of resources imposing negative impacts above a critical level, the agenda focusing on renewable resources and supplier management is on the way to meet the above said requisites. There have been important practices to develop sustainable operations management[80].

E. Sustainable Manufacturing

Sustainable manufacturing introduced from the series of meetings and conferences in 1980s on the contamination of environment and depletion of resources. Sustainability takes into account the long term control of strategies and considers three dimensions: Environmental, economic and social implications [93]. Mihelcic, et al. [94] proposed the definition of sustainability related to engineering context as the human or industrially driven paradigm which does not lead human's quality of life or impact adversely on economy, ecosystem and health. Sustainability issues arise from the actions of European Commission that has previously emphasized on concerns about environmental protection. The most updated policy regarding sustainability evolved from the document EUROPE 2020: A strategy for smart, sustainable and inclusive growth. Sustainability is often regarded as a thing or activity that maintains or keeps something or able to be kept [94]. Sustainable development defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainability at the product level requires the 6R concept (reuse, remanufacture, redesign, recycle, recover and reduce) unlike the traditional 3R concept of reuse, recycle and reduce as this demands closed loop multiple life cycle compared to the open loop single life cycle technique[95].

Table 6: Previous Literature about Sustainable Manufacturing

Author Name & Years	Methodology	Research Focused Area	Authors points of view
Ghosh, et al. [97]	Survey	Power production	In this paper, sustainability of wood-fuel operated power production plants in replacement of diesel fuel has been reviewed in various aspects like performance. Variation in load, environment impacts, energy consumption and cost of running.
Nambiar [98]	Theoretical	Manufacturing industry	Author explains some challenges related to organizations and presents solutions to adopt in their way to sustainability.
Niinimäki and Hassi [99]	Case study	Textile industry	The paper presents new design strategies to enhance product life and cost minimization thus maintain sustainable production. A traditional way of producing is to be replaced on design premises not by business perspective of consumer satisfaction.
Garbie [100]	Literature review	Manufacturing industry	This study focuses on sustainable development locally as well as globally for enterprises and provides a model based on review on various aspects of sustainability in economic dimension
Ngai, et al. [101]	Case study	Textile industry	A case study implementing five sequenced stages of maturity levels utility consumption and an information system for continuous improvement in energy utilization.
Alkaya and Demirer [102]	Case study	Textile industry	Authors point out various sustainable production applications based on environmental performance evaluation to minimize wastewater generation, GHG emissions, salts and water and energy consumption. Economic and environmental performances were evaluated. In addition, costs related to the pollution control have drastically been reduced.
Garbie [103]	Case study/ literature review	Manufacturing industry	This study presents an assessment framework and modelling of sustainability in three dimensions discussing the issues/aspects of sustainability. In addition, pillars, indicators and performance aspects related to sustainability are also highlighted.
Stock and Seliger [104]	Review/Case	Manufacturing industry	Authors explain the review of industry 4.0 and in the framework design, they point out various automated approaches collaboratively with human resources to achieve sustainability. Retrofitting use

Author Name & Years	Methodology	Research Focused Area	Authors points of view
			case has been developed using aspects of industry 4.0 in desktop machines.
Bhanot, et al. [105]	Literature review	Manufacturing industry	This study details the barriers and enablers on sustainability validated by various statistical approaches and presents a framework for organizations to meet their demands.
Gbededo, et al. [106]	Literature review	Manufacturing industry	A review study presents holistic approach towards sustainability and provides segmented and eco-innovative approach in the identification of sustainable product and process development. Authors provide a framework to the organizations moving in sustainable direction.
Stoycheva, et al. [107]	Multi-criteria decision analysis	Automotive Industry	The authors developed a quantitative decision analysis framework and suggested that material alternatives in manufacturing can be quantitatively selected based on sustainability objectives.
Deogratias Kibira [108]	Case Study	Power-Metal Product Manufacturing	Authors present a procedure for individual manufacturers to select KPIs for measuring monitoring and improving environmental aspects of manufacturing processes

At the process level, sustainability requires optimized technology and improved policies to minimize resource usage and toxic wastes and improved product lifecycle. While at the system level, sustainability takes into account all the stages like pre- and post-use. According to ISO 14040, Life cycle assessment is considered to be the common method to evaluate environmental impacts of manufactured goods [96]. Sustainable development goals (SDGs) in various countries aim to reduce per capita of food wastes and consumer's levels, resultantly moving towards sustainable resources.

Economically we utilize majority of our capital in disaster risk management alone to overcome the problems in flooding, earthquake and tsunamis. Efforts are taken to harbor renewable resources in power production and machines to limit the emissions of fossil fuels and issues on global warming. Environmental protection agency (EPA) provides the management policies with resources, tools and proper guidelines for organizations to utilize them for energy conservation and reduce environmental impacts.

IV. Results

Lean manufacturing has been regarded as one of the best optimization tools in various aspects. Taiichi Ohno and Shigeo Shingo initiated the practice of lean as Toyota Production system [26]. James P. Womach titles lean as “Machine that changed the world” in his book detailing the tools and their applications in companies [27]. Lean manufacturing provides promised reduction of wastes, however, the successful implementation demands to sustain its continuity [49]. Lean strategy primarily focuses on value addition, reduction of work in progress and scheduling of work. Naylor, Naim [28] describes lean as a tool to eliminate all the activities that contribute much time in scheduling process. Wastes are any activities that provide non-value addition to the system while value is anything the customer is ready to pay for. Some common tools like Kanban, 5S, Just-in-time, Kaizan, poka-yoke, virtual stream mapping, SMED have been functional in most companies.

However, the proper implementation of the tools is affected by cultural, technical and top management behaviors towards lean and many internal and external factors like employee's training and education, resources, government interventions. Thus, the goal to be achieved is not based on a single department, rather on the success of the whole firm. The Agile manufacturing, also regarded as flexible

manufacturing, focuses on meeting the demands of customers in shorter period of time. The term "agility" comes with the response of companies to the market variation. Agile manufacturing meets both qualitative and quantitative demands. The agile manufacturing initiated from the World War 2 period where the customers backlogs and needs could not be fulfilled [66]. That created a situation of preference based orders and quality degradation [30]. The trend shifted towards the automated processes with the aim of mass production and then later on towards the value focused production in 1980s.The core competence concept of agile based on the company's workforce and product is classified into individual and firm core competencies.

The individual core competence includes the individual's expertise, knowledge and attitude [31]. These can be improved through motivation and training of the employees. Lean aims at managing limited resources while agility aims at abrupt changes [65]. Agile manufacturing is not just the short term continuous improvement but also a way of doing business. Naylor, Naim [28] clearly states about agility that the company must remain updated and perform profitably in variable market place. For agile manufacturing to be successful, innovating workforce and flexible and intelligent technologies must be ensured [31]. Resilient manufacturing is the flexibility to withstand unexpected disruptions and external and internal influences on the supply chain, and return to the unaffected state. External risks are the influences due to natural disasters, price fluctuations and political and government involvements [76]. While internal influences emerge due to the incorrect information and workers poor performance. Thus the potential to deal with the risks and disruptions while maintaining the quality and quantity of goods is termed as resilience [76]. Flexibility and redundancy are two terms that constitute the resilient manufacturing. Flexibility is the ability to withstand the variations in the supply of raw materials and manufacturing techniques and redundancy can be estimated as having enormous supplies, manufacturing tools and transport facilities [32]. Visibility is another Aspect of resilience which is defined as to be efficient in the whole process of supply chain [33]. These three characteristics of resilience must be practiced to ensure the efficient supply chain process. Besides, Fiksel [34] states efficiency, diversity, adaptability and cohesion as four qualities of resilient manufacturing. To properly maintain the effective resilient supply chain, collaboration and risk management culture should be designed in the firm [35]. Risk identification, risk impact, risk mitigation and risk monitoring are four sequential process to overcome the risk and disruption management in any resilient supply chain.

Green manufacturing is the overcoming of global warming and hazardous pollutants impacting greatly on the environment. Environmental protection is becoming a vital factor in the manufacturing firms [85] and most of the European firms are taking steps to green their manufacturing systems considering environmental protection as primary objective besides quality improvement and cost effectiveness [86]. All the stages in supply chain play their role in environmental degradation; from suppliers through process to disposal [87]. However, after the introduction of ISO 14000, the companies considered green manufacturing as resourceful based on environmental management policies, but some still face problems of sustainable practices. Environmental management evolution found the focus in several companies as key area to be competitive in the global challenge [88]. The automotive industry makes major role in the environment degradation but some companies like FIAT, Volkswagen and BMW have their remarkable name in managing recycling processes [90]. Green manufacturing strategy for the processes is the conservation of energy and resources while minimizing wastes and toxic substances. Similarly green manufacturing strategy for products is to minimize environmental impacts throughout the cycle time of products [91]. The executives from all over the world agreed upon to cut down the resources imposing negative impacts and thus transition towards the renewable resources.

Sustainable manufacturing emerged from series of meetings and conferences in 1980s on environmental contamination and resource depletion. Sustainable manufacturing is a long term strategic planning and consists of three aspects: Environmental, economic and social sustainability [47]. Mihelcic, Crittenden [104] described the sustainability as human or industrially driven paradigm that does not affect human or economic or ecosystem's quality. Sustainability is often regarded as any activity that persists or keeps something or able to be kept [104]. Sustainable development defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainability at the product level requires the 6R concept (reuse, remanufacture, redesign, recycle, recover and reduce) unlike the traditional 3R concept of reuse, recycle and reduce [48]. At the process level, sustainability demands the innovative technology and policies to minimize resource usage and improved life cycle. While at the system level, sustainability takes into account all the stages of supply chain like pre-manufacturing, manufacturing, use and post-use. Sustainable development goals (SGOs) aims at reducing per capita of food and consumer's levels, moving towards sustainable resource efficient economy.

V. Discussion

The Lean, green, agile, resilient and sustainability are leading techniques of manufacturing. There is no doubt that each paradigm has its immense application in their own regime and its worth understanding. In order to understand these techniques, the focus of this study is the utilization and union of available previous related literature related to all these techniques (lean, agile, resilient, and green and sustainability) on one podium for understanding and generation of their interconnection with each other. The literature study revealed that the lean has a typical focus on the detection and reduction in wastes (non-value added activates) and agility focuses on how to handle customer demands and flexibility in orders with the confirmation of continuous production process without any interruption. The focus of agile manufacturing is to be responsive on product variety and the customer needs. For many firms the concept of agile and lean manufacturing seems similar but they are very different. Lean is to the strategies utilizing limited resources while agility is to the strategies with abrupt changes. The aptitude and ability of any system to pact with risks and disruptions without affecting quality and quantity of output and quantity of products considered as resiliency. In terms of green, environmental management, evolution found its focus in many companies as a key area to be competitive in the global challenge. The introduction of environmental management system based on green content has major impact on the operational strategy in different ways like product planning, procurement policies and logistics. Many companies have been aware of the environmental risks and green manufacturing; however, they could not be able to implement green approach due to the non-availability of suitable analytical approach. Sustainability is helpful but requires optimized technology and improved policies to minimize resource usage and toxic wastes and improved product lifecycle. Hence, this research work is an addition to the literature study that is supportive to bring out clarity that the combination of all these processes is very helpful for the sustainable production and the application of LARG idea in combination.

A. Contribution and implications

The scope of sustainable manufacturing is not limited to the production of the products which are sustainable, but it covers many other areas and aspects such as its impacts on lean, agile, resilient and green paradigms. For the achievement of this goal there are many efforts made by the researchers such as frameworks, theoretical models and roadmaps. Mostly these all techniques are concerned with the implementation of these approaches in step by step way for the utilization of tools and techniques in the reduction and elimination of all kinds of issues related to these paradigms. Thus, for finding the research gap the previous literature was investigated carefully, in order to confirm its existence. There were many articles found which were most relevant to this current work. The exploration revealed that there are few works on the combination of lean manufacturing and sustainability which shows encouraging effects on sustainable manufacturing. However, there is a still gap on the integration of lean practice which shows requirement of a framework for the integration of lean practices with 6Rs.

It was witnessed from literature, that the current research work is not only supportive for academicians, experts and engineering managers of respective field but it also provide assistance for those which are beginners in regards with lean and other paradigms. This research can be used as a key stone from the beginning to the end as to link lean, agile resilient, green and sustainability. Furthermore, in this study, there is a study on sustainability and its beneficial ability for engineering managers. This research will be very much helpful to resolve the issues which are or may happen on the involving these paradigms. As this research has studied, five paradigms would be supportive for convincing the top management towards its better understanding.

B. Limitations

This current research is typically a literature review inclusive of case studies, review articles and many frameworks and seems very much compatible in this present credential. However, as it was only a literature review, it lacks rigor of actual implementation of case study analyses and validation that is considered to be as a major limitation of it. So for overcoming this issue and increasing the generality of this research study, the authors have plans for future, that a proper framework need to be designed and it should be validated via case studies obtained from many other sectors.

VI. Conclusion

The Lean, agile, green, resilient and the sustainability are the leading optimization tools of supply chain in manufacturing sector. Each paradigm ensures the best promising remedy of the problems in the flow of supply chain. The focus of this study is on the search and selection of the previous related literature of all these techniques in one platform to gage the relationship among these and influence of one on the other. The literature study shows that the lean deals with the reduction of non-value added activities in the manufacturing processes and the agility focuses on to deal with the variable demands of customers while maintaining cost and quality. For many firms, the concept of lean and agile seems similar. However, lean strategy is utilizing limited resources while agile strategy is dealing with abrupt changes. The capability of any firm to deal with the disruptions and risks

without affecting the flow of supply chain is termed as resilience. The global challenge of environmental protection urged many firms to follow the policies of environmental management system and green their supply chain processes. Non-availability of suitable analytical approach has been a hurdle in the implementation of green manufacturing technique. Sustainability, among these paradigms, is a necessary attribute of supply chain and acts as an activator of the supply chain paradigms. This study is an elaboration and elucidation of the literature review to bring out the clarity that the combination of all these attributes is a promising tool for sustainable production.

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