Framework of Integrated Green Lean Six-sigma and Identified Barriers for Green Lean Implementation in Manufacturing Industry: A Critical Literature Review

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Abstract- A Green Lean technique has newly developed approach for organization to process operational and sustainability excellence. The main aim of this manuscript is to analyze the Lean Green Approach analytically and prospective benefits of Six-Sigma integration for improving its usefulness. On basis of literature, this manuscript is to analyze the synergies and diversifications of green and lean with their limitations. In addition, this paper suggests Six Sigma with DMAIC for solving manufacturing problem. The researchers, academicians and professionals can get some ideas from this paper about possible integration of Six Sigma with lean and green. It also identifies the barriers to a green lean implementation. To distinguish the correlation between barriers, Interpretive Structural Modeling (ISM) method can be used. Matriced Impacts Croise’s Multiplication Applique and Classment (MICMAC) analysis can be used to classify these barriers. The outcomes recommended that all recognized barriers play a significant role to clear the obstacle during implementation of green lean tasks.

NOMENCLATURE: DMAIC, Green lean, Six Sigma, Sustainability, Barriers, ISM, MICMAC

I. INTRODUCTION

In recent times, growing concern for the environment and growth of lean manufacturing, industrial sector dynamics have altered. In the past, productivity is key concernment for all industrialized sectors (Mohanty et al., 1999) [1]. On the other hand, with the proliferation of quality management tools and increased customer demands in addition to environmental modulation, companies have been enforced to reanalyze the management to improve their processes. In 1950s, lean manufacturing has been gained notoriety in a huge number of manufacturing industries around the globe to expand the concept of waste reduction (Chauhan et al., 2012) [2]. Latterly, to fulfill with environmental modulation and the public requests of market, green initiatives have been adopted (Digalwar et al., 2013) [3]. The integration of these two Green and lean appears insightful. Two queries emerge during combination, first is ‘can green and lean work jointly?’ Second is ‘their combination sufficient to successfully attain effective productivity and ecological outcomes?’ Lean is approved as a mainframe proposition which helps manufacturing sectors to enhance their ambitious and functional performance (Herron et al., 2008) [4]. On the other hand, Green is an initiative born of analyses for the environment and their new modulation excellence like pollution restriction and control (Digalwar et al., 2013) [3]. Some researchers discussed the combination of lean and green approach on industrial problems (Dues et al., 2013) [5].

All Green, Lean and Six-Sigma methods are compatible to each other. They minimize disadvantages of one another’s. The Lean value is estimated on the basis of its ability to identify waste. It does not include environmental problems (Lapinski et al., 2006)[6]. Therefore, our aim is to consider green gaps and also assess the impacts of integrated waste (Guggemos et al., 2005) [7]. Jointly, Green and Lean are able to distinguish waste and assess their environmental influence, even though they did not impart a real procedure for reducing waste. For this, Six-Sigma has been introduced to furnish this gap (Han et al. 2008) [8]. Cherrafi et al. (2016) [9] proposed a framework of integrated Green Lean Six-sigma (GLS) that provides five-steps with their sixteen-phases of process for execution of Lean, Green and Six-Sigma effectively and also improve their sustainability performance. (Colicchca et al., 2017) [10] investigated intermodal transport method that can be approved for governing supply chains according to Green Lean perspective. (Garza-Rayes et al. 2015) [11] gave a systematic literature review to identify and define the research streams in which scholars have focused on within the area of green lean. In this case,( Garza-Rayes et al. 2015) [11] identified six research lines related to lean and green (a) Compatibility (b) Combination (c) Combination with other approaches like Six Sigma, Resilience and Agile, etc. (d) Suggestion for measurement methods (e) Performance impacts on financial, sustainability and operations etc. (f) Applications in various manufacturing sectors.
This has been acknowledged that manufacturing sectors overlook objections in the execution of Lean Green. However, despite recent attention paid to the study of this approach and the various research streams developed in this area, very limited research has been conducted to support its effective implementation. In the case of Verrier et al. (2017) [12] addressed Green Lean implementation in manufacturing sector to improve productivity. Cherrafi et al. (2017) [13] explored the factors for combining Green Lean Six-sigma for significant achievement in process development. Also identified the important barriers in manufacturing sector for the prosperous execution of Green Lean initiatives and studies their interactions and interdependence. The present study analyses and examines the divergences and synergies between lean and green and it also provide insights research on how to overcome these limitations.

II. LITERATURE REVIEW

Today, lean manufacturing is assessed the most influential new manufacturing prototype with pragmatic affirmation. This enhances the ambitious of organizations by minimizing the inventories and lead times. It also improves product quality and productivity (Franchetti et al., 2009) (Garza-Rayes et al., 2012) [14, 15]. Today, increasing demand of sustainability for manufacturing sector is due to environmental and social concerns (Sezen et al., 2013) [16]. Environmental issues and the effectiveness of lean manufacturing, both contributed important role in green and lean prototype.

2.1 Synergies of Lean and Green

Lean tends to emphasis on waste reduction and furnished a better environment for developing green ideologies, creativities and tools. Lean applied industries implemented continuous improvement techniques that seem more inclined to accept environmental innovations (Mollenkopf et al.)[17]. In current situation, the comparison among these two are analytical which means less waste. However, Green goes besides simply reducing waste and it also addresses operation effectiveness, reduced material utilization and recovering. In any quality improvement approach, one of the most important goals is to enhance customer fulfillment. From this perspective it is attainable to recognize different synergies between the Green and Lean concepts. It’s namely waste demotion, time demotion and also the use of distinct propositions and proficiency to handle relationships with humankind, organizations and supply chain relations (Dues et al., 2013) [5]. Both the methods are intended to reduce costs (Lean) and to minimize the utilization of natural resources like CO2 production (Green) (Carvalho et al., 2011) [18]. Another is extreme inventory that considered wasteful in lean. In most cases, inventory increases delaying in to identify problems and discourages communication (Hines et al., 2004). ) [19]. Excessive inventory requires storage space, sometimes heating or cooling and must be illuminated during storage. From the environmental concerns, it can be assessed as wastage of energy when lighting, heating or cooling. (Franchetti et al., 2009) [15]. Therefore, it is feasible to link the seven lean wastes that are assessed and explained by the green capabilities. This recommends that lean can be assist as a enzyme for the environment and enables the implementation of corporate environmental strategies and operations. Still there are some sectors where green and lean cannot be incorporated as well as few limitations while examining green lean as an combined proposition.

2.2 Divergences of Lean and Green

The main difference between green and lean is that how waste can be defined (Dues et al., 2013) [5]. As discussed earlier, "waste" is any act that does not attach value to the customer. There is sufficient utilize of natural resources in the case of Green. Also, lean emphasis on space reduction, increased capacity utilisation, workforce reduction, system flexibility (Pattersen et al., 2009) [20]. Green applies practices such as reduction, reuse and recycling, reprocessing, restoration and reconstruction (Durate et al., 2013) [21] Lean emphasis on reducing costs and delays in order to persuade the customer (Carvalho et al. 2011) [18]. As in green, customers are greatly distressed about whether purchased products help them to be environmentally friendly (Dues et al. 2013) [5]. This is clear that lean and green are not fully like-minded and there are still some sectors where Green and Lean cannot be integrated. These areas did not prevent the use of green and lean at the same time as a single administration; on the contrary, they offer the prospect to get better both methods in a fully compatible manner.

2.3 Identify the barriers in manufacturing industry for Green Lean Implementation

Demonstrate recommended that several barriers have a major task in the combination and execution of Lean and Green (Cherrafi et al. 2016) [9]. A very limited research has been done in Green Lean Implementation up to till date. Risk management problem as a phenomenon of integration has been recognized by these obstacles (Cherrafi et al., 2016) [9]. As a result, the challenges of deploying Green Lean not only relate to the construction of the proposal but also to the political, managerial, behavioral and technical features. In this view, it is clear that these challenges are
not only related to one domain and have a complex nature underpinned by certain implementation barriers. Moreover, in practice, the different barriers may not have a similar impact when implementing Green Lean initiatives, particularly, in the manufacturing industry. Hence we argue that there is a need to investigate the barriers affecting the adoption of Green Lean. With this, this research also contributes to the practice of Green Lean by assisting top management and policy-makers in identifying, managing, prioritising and addressing the barriers that may impede the successful execution of lean and green. On the basis of this disagreement and a limited of amount of information generated in this region. The key research objectives of this study are:

a) Classify the barriers that may obstruct the prosperous combination of Green Lean capabilities.
b) To explore and establish the appropriate relationship among the barriers to better understanding the different effects of the impending factors that will stop organisations from successfully integrating Lean and Green and implementing them concurrently.

Table 1: Classification of Barriers in Green Lean implementation

<table>
<thead>
<tr>
<th>S.No</th>
<th>Barriers</th>
<th>Description</th>
<th>Researchers</th>
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<tbody>
<tr>
<td>1</td>
<td>Inadequacy of environmental responsiveness</td>
<td>Environmental perception must be required for successfully implementation of GLS concept</td>
<td>Zhu et al. (2004) [22]</td>
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<tr>
<td>2</td>
<td>Contest and insecurity</td>
<td>When the supply chain operates in an uncertain environment then competition becomes more difficult to manage</td>
<td>Arnheiter et al. (2005) [23]; Mollenkopf et al. (2010) [24]; Johnsson et al. (2014) [25]</td>
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<td>3</td>
<td>Finance constraints</td>
<td>In order to provide remunerative, community-based and environmental benefits to GLS concept, funds must be perfused more in the initial instants</td>
<td>Ravi et al. (2005) [26]; Panwar et al. (2015) [27]</td>
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<td>4</td>
<td>Lack of Kaizen tradition</td>
<td>The Kaizen Continuous Improvement philosophy can lead organizations to achieve continuous and sustainable benefits</td>
<td>Chaplin (2014) [28]; Johnsson et al. (2014) [25]; Kurdev et al. (2014) [29]</td>
</tr>
<tr>
<td>5</td>
<td>Poor quality of human material goods</td>
<td>Employees must be acknowledged as one of the organisation's key assets to succeed</td>
<td>Ggowindan et al. (2014) [30]; Jabbour et al. (2016) [31]</td>
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<td>6</td>
<td>Inadequacy of authority support to combine these practices</td>
<td>Authority must provide some financial support to the organisation for implementation of GLS concept</td>
<td>Al-Khadir et al. (2009) [32], Greer et al. (1996) [33]</td>
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<td>7</td>
<td>High Cost</td>
<td>Cost is the main factor for successful implementation of GLS concept</td>
<td>Florida (1996) [34];</td>
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<tr>
<td>8</td>
<td>Lack of communication and cooperation between departments</td>
<td>Communication and cooperation must be required for successful implementation GLS concept</td>
<td>Holland et al. (1997) [35]; Revell et al. (2003) [36]</td>
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<tr>
<td>9</td>
<td>Resistance to change</td>
<td>Any organisation must be flexible to adopt all things that must be required for successful implementation</td>
<td>Wang et al. (2014) [37]; Lucato et al. (2015) [38]</td>
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<td>10</td>
<td>Inadequacy of visual and statistical control during Green Lean Six sigma implementation</td>
<td>Visual inspection can help identify errors, while statistical control can help to analyze the extent of error</td>
<td>Katayan et al. (1996) [39]; Puttanaik et al. (2010) [40]</td>
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<tr>
<td>11</td>
<td>Unsupportive tradition and lack of motivational and encouragement</td>
<td>Organisational tradition can help an organisation to attain long term as well short term targets by encouraging and inspiring workers</td>
<td>Ravi et al. (2005) [41]; Johnsson et al. (2014) [25];</td>
</tr>
<tr>
<td>12</td>
<td>Unproductive time optimization</td>
<td>Unproductive time optimization can direct to untapped use of resources</td>
<td>Hines et al. (2006) [42]; Albliwi et al. (2014) [43]</td>
</tr>
</tbody>
</table>
Inadequacy of statistical green and lean thinking  

The viewpoint of GLS took into account for environmental, economic and social benefits  

Antony(2004)[44],Soti et al.(2010) [45];

Unsuitable classification of actions and areas to be greened and leaned  

Data mining analysis were crucial steps to properly identify areas for improvement  

Soti et al.(2010) [45]; Johansson et al.(2014[25]);

Inadequacy of education and expertise training  

Inadequacy of well designed training programmes can delay the provision of individual assets  

Soti et al.(2010)[45];Pannizzolo et al. (2012) [46]

It is important to note that some of the Green Lean barriers were reviewed separately as no prior research in this direction has been reported. However, feedback from experts and scholars in the field helped to overcome the obstacles so that they could become meaningful and adapted to lean green. In addition, some Green Lean integration suggest that the same constraints and challenges for their individual components are inherent, as two concepts have similarities (Garza-Rayes et al., 2012) [14].

Figure1. Similarities & Differences among Green and Lean Concepts (Modified from Dues et al. 2013) [5]

From this study, the following elements were been found to be common: people and organization, lead time reduction, Waste and waste reduction technique, relationship of supply chain and service level. They concluded that a lean acted as a catalyst to assist Green implementation. Also, it is challenge for the organisations to remove all the barriers in the first phase of Lean and Green implementation. Since these barriers may not have the same impact on GLS implementation. A further investigation was determined to be necessary. This directed the research to the exploration and establishment of the contextual relationship among different barriers.

III. METHODOLOGY: FRAMEWORK OF GREEN LEAN SIX SIGMA

For integrating these three methods Green, Lean and Six-Sigma, a framework was developed to improve the quality of products and reduces negative environment impact in any business sector. All three approaches of GLS are complimentary to each other and possess potential to overcome disadvantages of others (Banawali et al. 2014) [22]. Integration of GLS approach contributes a inclusive methodology that reduces the waste, negative environmental impact and delivers high quality products to the customer (Enache-Pommer et al.2010; Salah et al.2010) [23]. Till date, very little evidence of GLS framework has reported in the literature. In 2014 Banwai et al. [22] provided a framework for integrating GLS to improve the construction process. The framework provided by them was confined to construction sector and did not provide valuable insight about the way, in which the framework can be implemented to other sectors. The existing framework does not offer sufficient information about embedding Lean and Green within the DMAIC methodology, which remains the cornerstone of GLS program. Furthermore, it does not give any information regarding the readiness measures (critical success and failure factors) that are the prime importance for inspection of GLS in every organisation.
In present framework here, the author made a meticulous way to embed Lean and Green at every stage of DMIAC with associated tool sets so that organisations have a better understanding to implement GLS. The proposed framework here is more detailed and will provide the business sectors to introduce GLS in their concerned organisations with relative ease and in a comprehensive way. DMAIC five phase methodology provides a systematic framework of integrated GLS and offers a distinctive way of linking and sequencing tools of Lean, Green and Six Sigma. Below discussion shows the integration framework of Lean and Green tools via different phases of Six Sigma.

Phase 1:  
The define phase of Six Sigma is related to identification of Six Sigma projects, their prioritisation and selection of most appropriate project based on weighted scores obtained from project prioritisation matrix. In addition, this step of DMAIC decides the scope, schedule and team members of the identified project so that a project charter may be developed. For the selection of projects, Six Sigma methodology’s emphasis on voice of customer, voice of business and potential areas of ineffectiveness. This strongly recommends that Lean measures (Waste) and Green measures (CO2 emission, energy consumption rate, reuses factors etc.) may be considered as potential key areas for project selection.

Phase 2: The measure phase of Six Sigma is related to characterizing the process, brainstorming, developing reliable metrics, performing measurement system analysis to find out the capability and Six Sigma level of the process (Rathi et al. 2015a) [24]. In order to combine Six Sigma with Green and Lean, various associated Lean and Green wastes (CO2 consumption, water and energy utilisation, inventory and material utilisation etc.) are identified. Besides, these specific matrices for electricity: KWh, reuse factor, Green energy coefficient etc; for CO2 emission: tons/month can be made. Various sources of Green Lean wastes are found by performing the sustainable value stream mapping. It is quite essential to perform the measurement system analysis in order to check the repeatability, reproducibility and bias of measuring instruments. So, whenever the measurements are being made the instruments, they provide reliable data that ultimately measure of process, its capability and sigma level.

Phase 3: The analysis phase of DMAIC methodology reduces the variables and identifies the vital few factors for process improvement (Moosa and Sajid et al. 2010) [25]. In integrated GLS motel, this phase evaluates the main causes of wastes, in the considered parameters. This phase of integration deals with exploration of various potential causes and identification of root causes of defects with the help of statistical tools like analysis of variance (ANOVA), scatter chart, hypothesis testing, regression etc. (Ruben et al. 2017) [26]. Besides, Life Cycle Assessment (LCA), 5whys analysis, Cause and Effect diagram, 5whys analysis, process integration based on pinch analysis etc. (Raval et al., 2017) [27] are used at this phase to unearth various causes of wastes or unnecessary use of natural resources.

Phase 4: In the improve phase various potential solutions are proposed, tested and implemented to ride out the main causes of problems. To impetus the development of possible and most appropriate solution for the eradication of
various Lean Green wastes, this phase uses tools like pugh matrix, solution matrix, cost benefit analysis, life cycle interpretation (LCI), design for environment, VSM environmental, 7’S, kaizen, hypothesis tests, design of experiments etc.(Ruben et al. 2017) [26]. The solutions provided at this stage may be up cycling, anaerobic digestion, refuses derived fuel, recirculation or recycling of water by a cross flow microfiltration process or covering with the layer of calcium carbonate (Urbaniec et al. 2017) [28]. In addition, Green building (Sharma et al. 2017) [29] aims to utilize of management system of electrical power to follow energy practices, variable frequency drive to transfer energy intelligence into energy usage action, use of electronic data interchange to track inventory of the system, eco driving, model shifting.

Phase 5: The control phase of the integrated GLS approach deals with the sustainability of sigma level achieved in improvement phase (Prashar, 2016) [30], analysis of results obtained and take corrective measure (Singh et al. 2014) [31]. The entire process is reevaluated using VSM and life cycle assessment (LCA) to find out the level of waste reduction (Banawali et al. 2014) [19]. In this phase various observations, data collection and interactions and control charts are used so that monitoring of various Lean Green wastes viz, water consumption, electricity consumption, inventory and raw material can be done. As discussed in above section, incorporating selective tools of Lean and Green approaches in different phases of Six Sigma DMAIC methodology one can integrate and implement GLS effectively.

3.1. Research Approach (Identification Of Barriers And Their Contextual Relationship)

From the literature review, there are two main objectives formulated for the implementation of Green Lean implementation.

Identification of barriers-SLR

Contextual relationship among barriers –ISM

3.1.1 Identification of barriers through Systematic Literature Review (SLR)
An obstacle is considered a hurdle or obstacle which does not help or restrict the progress of an organisation to achieve successful Green and Lean integration and implementation. In order to identify these obstacles, Systematic Literature Review method was being embraced in accordance with its reproducible, precise, explicit and accurate approach to tackle objectives of research and issues (Kitchenham et al. 2007) [32]. Particularly, there are five sequences of the SLR proposed by Denyer et al. [33] were followed: (a) Targeting (b) Selection and Assessment of Research (c) Locating study (d) Analysis and Synthesis (e) use results for reporting

3.1.2 Contextual relationship among barriers –ISM
After identifying the barriers in manufacturing sector by using Systematic Literature Review and then approved in discussion with experts of industries and academics. Then Interpretive Structural Modeling method can be used to establish contextual relationship among obstacles and main aim to build up a hierarchical model of these obstacles. Main sequential phases of ISM as suggested by Mathiyazhagan et al. [34] were followed: (a) Questionnaire development (b) Data collection (c) Development of Structural Self interaction Matrix (d) Formation of Initial Reachability Matrix (e) Formation of Final Reachability matrix (f) Level Partitions (g) Formation of ISM based model (h) MIMAC Analysis.

IV. RESEARCH GAPS IDENTIFIED AND SCOPE FOR FUTURE STUDY
The present study reviews literature which is being published between 1991 and 2017 on Green, Lean and Six-Sigma. The existing literature review discusses the theoretical elements for developing an incorporated model and motivates researchers who engage in the areas of Green, Lean and Six-Sigma. Also, this study prevent analyzers and professionals from making unnecessary gaps in existing literature to develop a research plan

- Small medium size enterprises has applications of Green, Lean and Sustainability
- Frameworks, methods and models
- Improvement proposal for definite manufacturing industries and operations
- Social dimension
- Service industry has application of Green, Lean and Sustainability
- Geographic context
- Pre-implementation phase

A literature gap exists to identify the barriers in manufacturing sector and then establishes contextual relationship between these barriers. The dynamics of these barriers must be examined to facilitate its elimination. Lean manufacturing has been introduced and registered in the automobile industry. Several analyzers have been renowned
that it can be adopted in different manufacturing zones. Suitable obstacles must be removed in these industries if necessary. The modeling of the structural equation can always be applied to validate the existing model. To quantify the obstacles, game theory can be applied in a future study.

V. CONCLUSIONS

This study examines the literary texts on Lean, Green and Six-Sigma combination and problems that arise in this area. This review allowed us to identify existing gaps and to distinguish theoretical parts from the combination simulation. Also, it has been acknowledged seven key research deficits which are appropriate for succeeding exploration in this field. However, theoretical and factual concerning lean and green is narrow. The surveys were organized that are aimed at studying differences and synergies between lean and green as well as some other theoretical issues. The study provides variety of benefits for Green, Lean and Six-Sigma. The analysis also suggested a structure for the combination of Lean, Green and Six-Sigma. Six Sigma methodology DMAIC is also applied to integrate with Lean and Green. The paper gave some preliminary discussions on how Green Lean could exploit from the combination of Six-Sigma and the creation of a consistent Green Lean approach. Our research has two limitations. Firstly, in this study, there are themes and books in the literature review; however, some steps have been removed to secure attributes of the preferred papers. Secondly, in this study, there will be used of hypothetical classification for identifying the conceptual parts of the model and perforation in the literary texts. Further 15 barriers were identified in manufacturing sector that will create problems for successfully implementation and integration of Green, Lean and Six Sigma. All these barriers must be removed. The ISM technique is most suitable approach to distinguish interrelation between the obstacles to execute Lean, Green and Six-Sigma approaches in the manufacturing sector. MICMAC’s probe has been helped to bring these obstacles together into dependent, linkage and driving barriers, which will assist to employers and professionals to overcome them and achieve their goals of sustainable business management.

VI. REFERENCES

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