

Green Lean Six Sigma for sustainability improvement: a systematic review and future research agenda

Green Lean Six
Sigma

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Abstract

Purpose – The main purpose of this study is to explore different aspects of the Green Lean Six Sigma (GLSS) approach, application status and potential benefits from a comprehensive review of the literature and provide an avenue for future research work. This study also provides a conceptual framework for GLSS.

Design/methodology/approach – To do a systematic analysis of the literature, a systematic literature review methodology has been used in this research work. From the reputed databases, 140 articles were identified to explore hidden aspects of GLSS. Exploration of articles in different continents, year-wise, approach-wise and journal-wise was also done to find the execution status of GLSS.

Findings – This study depicts that GLSS implementation is increasing year by year, and it leads to considerable improvement in all dimensions of sustainability. Enablers, barriers, tools and potential benefits that foster the execution of GLSS in industrial organizations are also identified based on a systematic review of the literature.



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Originality/value – The study’s uniqueness lies in that, to the best of the authors’ knowledge, this study is the first of its kind that depicts the execution status of GLSS, and its different facets, explores different available frameworks and provides avenues for potential research in this area for potential researchers and practitioners.

Keywords Lean Six Sigma, Green Lean Six Sigma, Sustainability, Enablers, Barriers, Framework

Paper type Literature review

1. Introduction

Over the past few decades, economic change, sustainable product demands, governmental policy toward climate change and market influence have led to a surge in the level of competition. The human-driven actions and fast industrial development have raised the temperature of the earth’s surface by 1.5°C in many world regions (IPCC, 2014). The industrial sectors contribute about 35% of the worldwide emissions of greenhouse gases (GHGs) (Thirupathi *et al.*, 2019). This can be credited to the conventional approaches to production acquired by manufacturing sectors in most countries (Wang *et al.*, 2019). The increase in global emission of GHGs has led to severe health problems in different parts of the world (Kwon, 2020; Jacobson, 2008). Therefore, emissions related to industry and other man-made actions and their health impacts have compelled the manufacturing sectors to implement sustainable production methods. Furthermore, because of the pressure of strict government policies on climate change and the motive of the Paris pact, industrial sectors have to implement sustainable practices. Therefore, the manufacturing sectors are expanding massive investments in research and development to evolve other ways of manufacturing high-specification eco-friendly products (Sharma *et al.*, 2016). In several manufacturing areas, various ideas and strategies have been fostered during the previous decades like green manufacturing, value engineering, Six Sigma, Lean Six Sigma (LSS) and Green Lean Six Sigma (GLSS) to attain functional excellence in the organization (Pandey *et al.*, 2018).

Organizations use the lean concept to create value by improving the process through the identification and removal of different wastes (Garza-Reyes *et al.*, 2016). However, the Lean approach reduces waste but cannot address process variations and ecological effects. Thus, the requirement of Six Sigma and Green technology was observed to manufacture high-quality eco-friendly products at a lower cost. The green concept was more associated with thinking about protecting natural resources through manufacturing and was significantly related to sustainability (Zhu *et al.*, 2018; Huo *et al.*, 2019). It is a novel approach that minimizes harmful environmental impacts and focuses on the cost-effectiveness of an organization by producing high-specification eco-friendly products (Haapala *et al.*, 2013; Yadav and Gahlot, 2022). However, this approach conveys the ecological problems but does not minimize variations in the process. Therefore, the requirement of Six Sigma was felt to manufacture a process with a lesser variation. The six sigma concept generates value through reliable process output by recognizing and minimizing variations (Kazancoglu *et al.*, 2018; Shokri, 2017; Silich *et al.*, 2012). This approach minimizes process variation but does not reduce negative environmental impacts and related wastes in the process (Sun *et al.*, 2017). Lean and Six Sigma are two widely adopted methods that lead to the improved sustainable performance of an organization (Arnheiter and Maleyeff, 2005; Antony *et al.*, 2019). In recent years, there has been a vivid development in LSS. Success stories of LSS execution and consequent enhancements in industrial sectors throughout the globe have been exhibited in academic journals (Shah *et al.*, 2008; Pepper and Spedding, 2010). But LSS is also not able to address societal and ecological issues associated with the process and industrial organizations. The integrated GLSS approach focuses on enhancing resource efficiency and mitigating harmful

environmental effects and aims to improve the customer's overall satisfaction level (Chaudhary and Mudimela, 2022).

As GLSS is much devoted to enhancing the green performance of the industries, so, this approach will be helpful to attain two targets of the COP 26 conference (Deif, 2011). As GLSS is a novel methodology, it is essential to consider different theoretical elements related to this approach like readiness measures, barriers, potential benefits and a review of available GLSS frameworks/methods. In the literature, there is no evidence on the study occurs that dispenses a thorough exploration of GLSS literature, in conjunction with different theoretical elements related to this approach. The current study's objective is to opt for GLSS approach implementation in manufacturing sectors by discerning the research gaps and methods used by distinct researchers and practitioners. This study answers the following research questions:

RQ1. What are the different facets (enablers, barriers, tools, benefits) of GLSS that foster promote and adopt this sustainable approach?

RQ2. What are the current status of the implementation of GLSS, gaps in the studies and possible avenues for future research?

This manuscript is categorized into seven sections. Section 1 represents the introduction part of the current work. Section 2 depicts SLR, a literature survey concerning Lean, Six Sigma, Green, LSS and GLSS and different theoretical elements related to this approach. Section 3 reports the adopted research methodology in the current study. Section 4 presents a descriptive analysis of the chosen manuscript in detail. Section 5 highlights outcomes from the existing literature gaps recognized and the future direction of the current research. Section 6 presents the purposed GLSS framework, and Section 7 presents the conclusion, implications and limitations of the recent research.

2. Literature review

This section first outlines the literature research methodology. Then the literature was surveyed according to the points of view of Lean, Green, Lean-Green, Six Sigma, LSS and GLSS approaches, respectively.

2.1 Literature search methodology

To do a literature review, the authors have followed the systematic literature review (SLR) methodology (Figure 1) (Kaswan *et al.*, 2021). SLR provides an explicit view of the literature review and the uniqueness of the study (Kaswan *et al.*, 2021). There are three different phases to realizing the SLR. In the first phase of SLR, the study's objectives are identified. The main objective of the present research work is to find out the current status of the implementation of GLSS and suggest future research dimensions. Based on the research objective, in the second step of locating the relevant studies, different electronic databases (EDB) Springer, Elsevier, Taylor and Francis, Emerald, Inderscience, Scopus and Google Scholar databases were searched. After that, the search strings or keywords were used. In this study research papers were identified using the keywords Lean, Six Sigma, Lean-Green, LSS, GLSS, Sustainability, barriers, framework, manufacturing, etc. To select pertinent articles related to the study, first, the authors used the chosen keywords in the reputed database to identify all the articles. The exclusion criteria of the study directly related to the theoretical concept of Lean, Six Sigma and LSS were neglected. Further, all articles related to conferences, book chapters and unpublished data were neglected. This leads to the final selection of the 140 articles pertinent to the research work. By using search strings, we

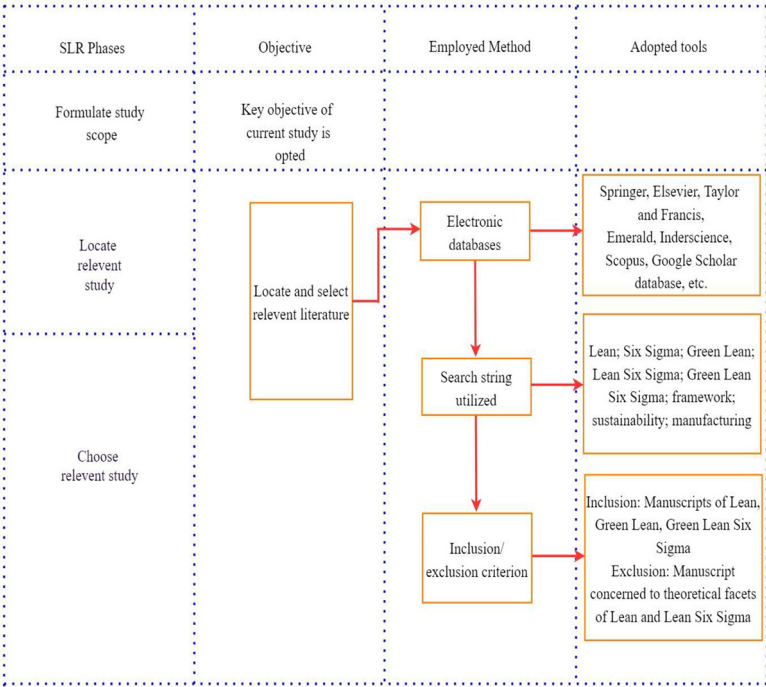


Figure 1.
SLR methodology

Source: Adapted from Kaswan *et al.*, 2021

identified 140 articles. Once the 140 articles have been identified, the authors critically investigate all the articles to identify different facets related to the GLSS implementation and other hidden areas that are not explored to date.

2.2 Lean manufacturing

This concept was acquainted with Toyota Production System and acquired recognition after the book titled “The Machine That Changed the World” was published (Womack *et al.*, 1990). It is a systematized approach to identify and remove wastes of all non-value-added actions by consistent enhancement that high-performance manufacturing sectors have executed to obtain extraordinary outcomes (Chugani *et al.*, 2017; Antony *et al.*, 2016). The mitigation or minimization of any waste will boost efficiency, decrease costs and initiate the organization’s more unassuming on the global market (Kaswan and Rath, 2021a, 2021b; Galeazzo *et al.*, 2014). In manufacturing sectors as well as for the service sectors, lean strategy has been demonstrated as a significant methodology for the development of an organization (Raci and Shankar, 2005). Rath *et al.* (2021) proposed an integrated framework model for the GLSS approach. They recommended that the green concept must be connected with the lean concept to minimize the harmful effects of lean. The pragmatic applications of lean are used in the participation of employees through using tools and methods like Kaizen, Kanban, 5S, poka-yoke and value stream mapping (VSM) (Singh *et al.*, 2021; Martinez-Jurado and Moyano-Fuentes, 2014).

2.3 Green technology

Green technology is used to minimize pollution and waste by reducing natural resource use. This concept also uses the 3R technique (reduce, reuse and recycle) to mitigate waste and emissions. Most companies have launched the “Go Green” mission statement to mitigate the harmful environmental impacts of their operations (Gaikwad and Sunnapwar, 2020). Llorach and Roncero (2020) recommended that this concept is a vital innovation to upgrade eco-business and sustainable growth. The waste generation rate, energy consumption levels and contamination levels are continuously increasing in organizations (Gandhi *et al.*, 2018). That is why the government initiates strict rules and regulations on the industries to adopt green technology in their operations. The pragmatic application of green manufacturing is used in discipline and appropriate training to the employees by using various practices such as waste recycling, life cycle assessment (LCA), green designing and packing (Rehman and Shrivastava, 2013; Vinodh *et al.*, 2011).

According to Garza-Reyes (2015), green manufacturing as an ideology determines, measures, evaluates and controls ecological waste by solving product and process problems. Digalwar *et al.* (2017) identified and developed the structural interrelationship between distinct variables for the effective execution of GM. The study reveals that top management commitment has the most significant driving power for executing this strategy. According to Kazancoglu *et al.*, (2018), green manufacturing includes several environmental strategies in the form of, green purchasing, green packaging and green design. According to Prasad *et al.* (2016) ecological strategies in the form of eco-labelling, environmental management systems (EMS) and ecological regulations have created a huge demand for green manufacturing in industrial sectors. Karuppiah *et al.* (2020) identified 25 barriers to the execution of GM in Indian small and medium enterprises (SMEs) through a comprehensive literature review and expert opinions. The recognized barriers are further ranked using DEMATEL, ANP and TOPSIS techniques. Gedam *et al.* (2021) identified eleven barriers to the execution of GM through the literature review and consultation with industrial personnel. Further, the identified barriers are ranked by using the ISM-DEMATEL methodology.

2.4 Green Lean

The difference between lean and green waste is that the first is about non-value-added activities, and the second is about needless utilization of water, electricity and natural assets (Mollenkopf *et al.*, 2010; Marco-Ferreira *et al.*, 2020). Gadekar and Gadekar (2014) introduced an incorporated framework for these practices for attaining both financial and ecologically sustainable performance in an organization. Pampanelli *et al.* (2014) believed that the green and lean concept could decrease resource utilization from 40% to 60% on a normal and could diminish the total expense of energy needed for manufacturing. Garza-Reyes (2015) carried out a systematic review of the existing literature on green and lean. This review aims to contribute by stimulating researchers to study further this field in-depth, which will assist in a better understanding of the compatibility and impact on organizational performance of lean and green strategies. Lu *et al.* (2019) presented a framework in the construction sector to assess GHG emissions. Yadav *et al.* (2021) developed a framework for visualizing and evaluating the manufacturing process performance. This framework will facilitate the industrial sectors to overcome challenges related to integrating and executing green and lean approaches.

2.5 Six Sigma

Six Sigma emphasizes continuous and breakthrough enhancements to minimize the cost of production, improve the satisfaction level of customers and predictably produce high-quality

products and services (Noone *et al.*, 2010; Thomas *et al.*, 2009). It is a closely controlled approach that minimizes variation in the process so that defects are minimized to less than 3.4/M opportunities (Rathi *et al.*, 2022b; Kumaravadivel and Natarajan, 2013). SS methodologies were not confined to enhancement impacts on the shop floor, but they also affected distinct aspects of manufacturing sectors (Haikonen *et al.*, 2004; Fatemi and Franchetti, 2016). Schroeder *et al.* (2008) dictated that SS group members use advanced root cause analysis methods and acquire outstandingly more control and investigation concerning an issue compared to any other quality enhancement strategy. Mehrjerdi (2011) determined the SS DMAIC methodology application that included describing the problem to the control of the method to improve output. The key objective of SS is to attain the quality of products by enhancing the process and mitigating source causes of defects (P. Kumar *et al.*, 2017). Antony *et al.* (2005) presented an analysis of the status of SS execution in SMEs in the UK. This method tries to estimate prevailing execution measurements and explores how the needed and optimal concert level could be accomplished (Mudimela and Chaudhary, 2020).

2.6 Lean Six Sigma

The term “LSS” was first used in the beginning phase of the 2000s. Several authentications accessible in the existing literature have upheld the probability of incorporating LSS and their significant effects on the performance of the manufacturing sectors (Drohomeretski *et al.*, 2014; Chaudhary *et al.*, 2020). Arnheiter and Maleyeff (2005) tried to eradicate Six Sigma and Lean drawbacks by incorporating them that encouraged incorporation. Shahin and Alinavaz (2008) attempted to exhibit the different and relative methodologies of LSS. The unified effect of Six Sigma and lean tools dispenses the best solution for the industrial sector at reasonable costs. Sunder (2016) proposed an LSS model for shareholder management in the Banking and economic sector and also used the LSS philosophy in service areas like retail banks and acquired a profit of INR 1.6 m.

Snee (2010) momentarily clarified the survey of 16 years of LSS and discovered eight significant attributes, which were the functioning component for effective execution. Antony (2011) emphasized the crucial transformation between Six Sigma and Lean for process excellence execution in manufacturing sectors by accompanying the views of academicians and experts throughout the world. Drohomeretski *et al.* (2014) studied the execution of Lean, Six Sigma and LSS to investigate the explanations that encouraged the industrial sectors to embrace such enhancement strategies and recognized that cost minimization was the critical cause for industries to execute these approaches. Albliwi *et al.* (2015) carried out a SLR on this concept for industrial sectors and depicts distinct issues like profits, encouraging factors, approaching aspects and drawbacks. Case study-based research can be carried out to recognize the prospects for LSS projects and major performance pointers of higher-education sectors (Sunder, 2016). Antony *et al.* (2017) illuminated the execution of LSS from the previous fifteen years and recognized the basic elements of the same like the involvement of top leaders, dedicated management leadership, cooperative organizations, dedicated management leadership and a complete strategy to enhancement incorporating the area of utilization and techniques used.

Prashar and Antony (2018) carried out an SLR on LSS in the food industry. The study reveals that human factors and food industry characteristics were recognized as the key barriers to implementing the LSS strategy. Singh and Rathi (2019) carried out a study to exhibit a comprehensive review of the benefits and critical challenges of the execution of LSS in business organizations and disperse literature in terms of many organizations wise, research methodology-wise and journal-wise. Gupta *et al.* (2020) carried out a study exploring the existing literature concerning the LSS concept. Big Data Analysis (BDA) has

been used in each phase of LSS. [Shokri and Li \(2020\)](#) represent a synthesis of present literature published in 2010 to dispense a general comprehension of the sustainable execution of LSS projects as far as task approaches instead of results. The study reveals that geographically and methodically comprehensive research works have been carried out on the integration of green manufacturing and LSS.

2.7 Green Lean Six Sigma

Every tool of GLSS can reduce the drawbacks of other tools; it implies it corresponds to one another that influences value addition because of its capacity to distinguish the wastage and assess its ecological effect ([Shokri and Li, 2020](#); [Rathi et al., 2021](#)). [Banawi and Bilec \(2014\)](#) proposed a framework that integrates GLSS to enhance the quality and ecological effects in the construction sector. They accomplished excellent outcomes as diminished waste in the quantity cover measure by executing the presented framework. [Kumar et al. \(2015\)](#) dissected the combining philosophy taken on by the manufacturing sectors through interviews, questionnaires, sustainably used overviews and workshops. This study also presented a framework for recognizing barriers, drivers and key execution measures of the GLSS approach.

[Cherrafi et al. \(2016\)](#) evaluated the existing literature on LSS and sustainability and recommended future investigation directions and possibilities for academic scholars and practitioners. They recognized the advantages of incorporating the LSS and sustainability. [Cherrafi et al. \(2017\)](#) reviewed 450 organizations (which incorporated SMEs and global companies) for recognizing the crucial elements of GLSS. The researchers proposed that more research can be leaned toward discovering the main components that affect the GLSS. [Kumar et al. \(2016\)](#) recognized 21 GLS barriers in the automobile sector of India through the literature review. Further, they were modelled by the ISM technique. [Cherrafi et al. \(2017\)](#) proposed a theoretical framework and equated results in four distinct sectors, which directed case organizations in executing the GLSS strategy. [Ben Ruben et al. \(2017\)](#) developed a framework for assessing the concert of Lean sustainable systems established on aspects recognized by adaptive neuro-fuzzy interface systems. [Erdil and Arani \(2019\)](#) presented a model, inspects each of the three components of sustainability and embedded sustainability objectives in LSS projects.

[Siegel et al. \(2019\)](#) suggested a generic framework for the execution of Green and Lean in the context of Indian SMEs. This research focused on success factors, challenges, tools and techniques, sustainability measures, frameworks and advantages of Green Lean in SMEs. [Kaswan and Rathi \(2021a, 2021b\)](#) proposed the integration and framework of GLSS. The integration of GLSS was developed dependent on hypothetical fundamentals and the framework was developed dependent on the DMAIC methodology. [Sony and Naik \(2020\)](#) suggested that GLSS integration will develop a robust approach and assist the manufacturing sectors to be sustainable. They also proposed a generic implementation framework, and to the best of the authors' knowledge, this is the first study in which it has been tested practically. [Kaswan et al. \(2021\)](#) carried out a study on the review of GLSS strategy along with readiness aspects, failure factors, integration and execution framework. This study investigates grey areas of GLSS and dispenses a methodical path to integrate Green, Lean and Six Sigma under the umbrella of GLSS.

2.7.1 Critical success factors for executing Green Lean Six Sigma strategy. Critical success factors (CSFs) are imperative for implementing any type of strategy in the manufacturing sector ([Rungtansamee et al., 2002](#)).

[Habidin and Yusof \(2013\)](#) recognized the following CSFs to execute LSS:

- leadership;
- structured improvement process;

- quality information and analysis;
- supplier relationship;
- customer focus; and
- focus on metric.

Cherrafi *et al.* (2017) recognized the following CSFs to execute the GLSS strategy effectively:

- organizational readiness to execute the GLSS approach;
- the project is chosen, and prioritization;
- a commitment of higher management and employees;
- communication; and
- resource and skills to facilitate the execution.

Singh and Rath (2019) identified 16 success factors to implement LSS strategy in micro-small and medium enterprises (MSMEs). Out of 16 CSFs, 10 CFs are prioritized using best-worst method. Raval *et al.* (2021) identified ten CFs for effective implementation of the LSS strategy in manufacturing sectors. The study reveals that top management is the most CSF and should execute in a step-wise methodology under the drawbacks of available resources.

2.7.2 Barriers and drivers for integration of Green Lean Six Sigma strategy. GLSS approaches are influenced by the assortment of drivers and barriers to their execution; thus, it is important to find out the significant drivers and barriers of this incorporation. Due to increasing demand and scarcity of resources, the cost of raw materials, energy and resources continuously enhances day by day in organizations (Diaz-Elsayed *et al.*, 2013; Kaswan *et al.*, 2019). Wong and Wong (2014) believed that this is intricate to predict manufacturing costs therefore industrial organizations require higher material proficiency to achieve improved functional performance. As per Luo (2013), each one of the manufacturing sectors is forced by consumers, controllers, contestants and shareholders to assess and adjust their methods to enhance societal and ecological development.

To implement the GLSS approach in the organization, it is imperative to identify the performance improvement GLSS barriers. Outcomes from the literature reveal that only a few works had been done regarding the identification of GLS barriers. Kumar *et al.* (2016) recognized Twenty-One GLS barriers in the automobile sector of India through the literature review. Further, they were modeled by the ISM technique. Cherrafi *et al.* (2017) identified fifteen GLS barriers from a SLR. Then, they were validated through ISM and MICMAC analysis. Hussain *et al.* (2019) recognized 24 barriers in the construction sector. Then, the ISM technique was used to establish the relationship between these barriers. C. Singh *et al.* (2021) identified 12 barriers by reviewing the literature. Using the DEMATEL technique, a cause-and-effect diagram was developed to identify the critical barriers. Singh *et al.* (2021) identified 16 barriers to implementing LSS strategy in MSMEs through opinion and experts and authenticated through statistical reliability theory. Furthermore, they are modeled by using the ISM technique. The study reveals that concerning management barriers are the most critical barriers. Furthermore, obtained results were validated through structural equation modeling (SEM).

2.7.3 Benefits of Green, Lean and Six Sigma integration. GLSS is commercial methodologies and processes that might help the industrial sectors. Different researchers intimated that executing these methodologies might successfully impact the company's performance (Dües *et al.*, 2013). As per Miller *et al.* (2010), GLSS can have a more significant, positive effect on central concern performance (financial, societal and ecological) when

carried out together as opposed to independently. The significance of this integration will be in industrial organizations where exclusively GLSS methodologies have been carried out to acquire sustainable advantages for industrial organizations.

2.7.4 Tools, techniques and methods. Several researchers propose numerous tools that help manufacturing sectors eliminate waste (Langenwalter, 2006; Yadav and Desai, 2017). These tools and techniques of LSS (Table 1) include LCA, JIT, TPM, Kaizen, VSM, 5S, C&E diagram and quality function deployment (QFD). These tools have been modified and expanded to gain more ecological and societal development (Kaswan and Rathi, 2021a, 2021b). But these tools and techniques should be painstakingly chosen and should be fitted with the manufacturing sector's set-up (EPA, 2003).

2.7.5 Review of existing frameworks, models and methods. Researchers have developed several frameworks, models and methods to integrate Green, Lean and Six Sigma (Table 2).

GLSS has been implemented in different industrial sectors to improve operations as well as environmental efficacy (Table 3).

2.8 Significance of digitization regarding Lean and Green

Lean and Green technologies are augmented by the incorporation of digital technologies like Industry 4.0 (I4.0). Dalenogare *et al.* (2018) integrated Lean with digital technologies and found that digital technologies can overcome the limitations of Lean especially when the product are differs in terms of variety. They also suggested that I4.0 must be incorporated after Lean is implemented, as Lean creates the process baseline, and then this process baseline can be automated and digitized. The same has been supported by Wang *et al.* (2019) who proposed that it is easier for the industry to incorporate digital technologies measures after they have already incorporated Lean measures. Although the integration of Lean and digital technologies is still in its infancy, initial evidence suggests integration of the two approaches leads to improvement in metrics related to waste, costs and productivity of the organizations. Also, it has been found that digital technologies moderate the effect of Lean practices on the operational efficacy of the industry (Huo *et al.*, 2019).

Integration of Lean aspects with Green technology also comes with many difficulties. As stated by Powell *et al.* (2017) and Ershadi *et al.* (2021), it tends to focus primarily on economic aspects of sustainability and overlook environmental ones due to a large number of environmental metrics. The inclusion of green metrics also involves many stakeholders such as the customer, organization, government, NGOs, etc. The wide spectra of constituents have different interests and sometimes conflicting ones that lead to difficulty in data gathering and further investigation. Thus, there is a need for big data and further examination of the same is required to make effective judgments on green measures of sustainability. Lean integration with digital technologies like Big data and the internet of things (IoT) will make the workplace "smarter," enhance decision capability and ensure improved environmental sustainability of the industry. IoT-based systems can be used to make the workplace more responsive and reduce hazards, as they provide quick information exchange and communication to achieve smart recognition, position and tracing (Patel and Keyur, 2016). Green technology coupled with digital technologies is further augmented by the adoption of artificial intelligence (AI), contributing to reduced workplace accidents and less human intervention in the system (Cheng *et al.*, 2020; Kaswan *et al.*, 2022). The adoption of other smart technologies, such as 3D printing, further supplements GLSS's pursuits to realize a product with reduced environmental damage (Spears and Gold, 2016). GLSS is further augmented by other digital technologies, such as collaborative and autonomous mobile robots (COBOT and AMR), augmented reality (AR) and digital automation with

Table 1.
Effect of distinct LSS
tools on
environmental
concern

LSS tools	Obtained environmental benefits	References
LCA	LCA technique will facilitate the organizations to search for the most accessible life cycles which are helpful for the mitigation of harmful impacts	Paolotti et al. (2016) ; Kamei et al. (2013) ; Kaswan and Rath (2021a, 2021b)
Kaizen	Kaizen is a continuous improvement process that has a positive environmental impact as the enhancement activities protect to minimize the scarps that also directly mitigate resource consumption	Vinodh et al. (2011) ; Chiarini and Vagnoni (2015) ; Torielli et al. (2010)
VSM	This technique has a pragmatic impact on the ecological concert. Its objective is to recognize waste in the value stream so that wasteful activities can be minimized. Its future map is used to eliminate environmental impacts	Kaswan et al. (2021a) ; Yadav et al. (2022)
5S	5S activities provide a safer working environment and eliminate all-inclusive resource consumption as systematization has been retained in the industries	Bae and Kim (2007) ; Wilson (2010) , Costa et al. (2018)
Cause and effect diagram	This diagram is used to recognize possible root causes of the problem or condition to improve the environmental performance of the organization	van Loon et al. (2014) ; Kennet (2008) ; Rios et al. (2019)
QFD	Customer needs can be incorporated with environmental necessities to convert them into practical needs	Garibay et al. (2010) ; Klochkov et al. (2016) ; Erdil and Arani (2019)
Source: Authors' own creation		

sensors, making systems more responsive, reducing lead time and supporting adaptation to self-decision-making in a complex environment ([Djuric et al., 2016](#)).

3. Research methodology

In the current study, a comprehensive literature review regarding the GLSS approach has been carried out. To select pertinent research articles, the authors have used the SLR technique. SLR is a process for recognizing, assessing and correlating the existing body of concluded and registered studies carried out by researchers, scholars and practitioners (M. [Singh and Rath, 2019](#); [Rathi et al., 2022b](#)). After developing the SLR, the theoretical background of Lean, Green, Lean-Green, Six Sigma, LSS and GLSS have been discussed. After that, different theoretical elements related to GLSS like CSFs, barriers, potential benefits and a review of available GLSS frameworks/methods have been explained in this methodology. Thereafter, a descriptive analysis of published articles has been carried out. The research methodology to perform this systematic analysis of the literature has been presented in [Figure 2](#). It presents the year-wise analysis of articles, journal-wise analysis of articles, continent-wise distribution of articles and approach-wise distribution of articles to explore different facets of the GLSS approach. From

Authors	Research stream	Framework/ Model/ Method	Major contribution	Drawbacks
Duarte and Cruz-Machado (2013)	Green and Lean	Projected and implemented model	Developed a model for executing lean and sustainability strategies. This presents how and when green and lean approaches can be synergetic and companionable with the help of the tools and principles of these two approaches	The major limitation of this model was that it was not corroborated in a real-life environment
Zhang and Awasthi (2014)	Six Sigma and Sustainability	Development of framework	Presented a framework that integrates Six Sigma and sustainability. It completely describes imperative steps to attain exactly sustainable development	The main drawback of this framework was that it did not emphasize economic development
Caiado <i>et al.</i> (2018)	Green, Lean and Six Sigma	Proposed and integrated framework	This article provides a comprehensive GLSS framework seeking to assist practitioners in standardizing it in several types of services by identifying nine critical factors for its execution	This study's major drawback was that the developed framework was not tested practically and was restricted only to service sectors
Subrata Talapatra (2019)	Green, Lean and Six Sigma	Proposed and implemented framework	Presented and executed the GLSS framework for the jute industry to reduce defects, carbon footprints and energy utilization	The proposed framework completely emphasized jute industry and did not include societal aspects
Kaswan and Rath (2021a, 2021b)	Green, Lean and Six Sigma	Proposed and implemented framework	The purpose of this manuscript is to incorporate and prosper DMAIC dependent GLSS framework. This developed framework provides a path for GLSS implementation by an appropriate preference for the task. The research work exhibits that several sustainability actions had been assessed with the assistance of exclusive GLSS indices and a toolset	The major drawback of the current study was that the framework of GLS has not been tested practically
Shokri and Li (2020)	Green, Lean and Six Sigma	Exploring the Green effect on LSS	The objective of this article is to implement a green strategy in LSS ventures in industrial organizations. This manuscript also distinguishes under which situations the yield of LSS developments with reasonable advantages is more ecologically sound	The main limitation of this work was that the present model is extremely distracted to describe the decision in LSS
Gholami <i>et al.</i> (2021)	Green, Lean and Six Sigma	Proposed and implemented framework	Presented and executed GLSS framework to improve organizational sustainability dependent on DMAIC methodology	The major drawback associated with this study was that the proposed framework had not considered the application of lean

Source: Authors' creation

Table 2.
Interpretation of frameworks, models and methods

the comprehensive review of the articles, potential research gaps have been identified for fostering the research plan. The analysis carried out provides several directions for future scope in the GLSS field. The current research presents both theoretical and practical implications for practitioners and researchers.

4. Descriptive analysis

4.1 Categorization of manuscripts according to the year of publication

The categorization of manuscripts according to the year of publication over the period from 2005 to 2021 has been done and 140 articles were identified from the same (Figure 3). This was reorganized from the studies of (Parmar and Desai, 2020) and (Gaikwad and Sunnapwar, 2020), where the manuscripts selected were plotted by the year, they were published. This indicates how the manuscripts were published and if the research is for sure depending on the current data. It shows the growing tendency of research manuscripts

Authors, year	Sector	Major contribution	Limitations
Izzaida <i>et al.</i> (2013)	Automotive industry	Established the interrelationship between GLSS and Management Innovation (MI). It also explores how GLSS can be encouraged and have a practical effect on establishing MI to obtain better performances in the automotive sector. This outcome minimizes waste generation, process variation and environmental impacts in this sector	GLSS framework and integration have not been presented
Banawi and Bilec (2014)	Construction industry	Presented a framework and integrates Green, Lean and Six Sigma in a commonsense strategy to improve the quality and ecological impacts of the construction process. This framework provides a comprehensive, multi-phase approach for the improvement in-process and minimization of the life cycle ecological effects in the construction process	This framework did not incorporate manufacturing industries and takes more time for the execution process
Garza-Reyes (2015)	Manufacturing industry	Presented the DMAIC methodology of the Six Sigma strategy to display that the SLR stipulates that integration of Green Lean may have expected similar drawbacks as the independent green and lean strategies, but these may be enhanced with the help of this strategy	This methodology has a scarcity of the application computation tools in various phases
Cherrafi <i>et al.</i> (2016)	Manufacturing Industry	Proposed a framework that methodically leads manufacturing sectors by a five-phase and sixteen steps processes to integrate and implement this strategy effectively to improve sustainability performance. The study reveals that average resource consumption and cost of energy or mass stream	This framework was that sensitive operations may be elaborated to enhance by this methodology

Table 3.
Depicts prominent research regarding GLSS in different industries

(continued)

Authors, year	Sector	Major contribution	Limitations
Mangla <i>et al.</i> (2017)	Automobile industry	reduce from 20% to 40% and 7%–12%, respectively, after executing this approach Recognized barriers in GLSS product development (GLSPD) from consultation with industrial personnel and an all-embracing literature review. Twenty-one barriers are recognized and authenticated by the brainstorming sessions. Then, Interpretive Structural Modeling (ISM) was used to initiate a hierarchical model of these barriers in implementing the GLSPD process in the automobile sector	GLSS framework was that it did not analyze properly
Ruben <i>et al.</i> (2018)	Manufacturing industry	Represented the effective execution of the LSS framework with environmental considerations to pledge the minimization of defects and ecological impacts. The study exposes that internal defects have been reduced from 16000 PPM to 5000 PPM. Environmental impacts were also reduced from 42Pt to 33 Pt	The LSS framework could be used only by automotive component organizations and definite manufacturing sectors working with analogous manufacturing operations
Powell <i>et al.</i> (2017)	Food industry	Climaxed the application of LSS and evaluates the impacts of LSS on environmental sustainability in food processing industries. This outcome minimizes process variation, rejections and ecological effects	Only one case company had been considered to carry out the research work
Zhu <i>et al.</i> (2018)	Health-care industry	Proposed a systematic framework dependent on an outdated DEF meta-modal that recommends specific measures and synergies between Lean and Green approaches. These outcomes in reducing the waste generation in the hospital operations and	The presented framework had not been tested practically

(continued)

Table 3.

Table 3.

Authors, year	Sector	Major contribution	Limitations
Sreedharan <i>et al.</i> (2018)	Public sector	successfully related greening to lean abilities may reduce environmental impacts within the hospitals Dispensed the GLSS modal for public sectors. This modal improves the efficient brilliance of public sector assistance like telecommunication, construction and health care. GLSS is integrated with supply chain management to eliminate obstacles resist by public sectors, leading to process enhancement	This framework lacks the comprehension and evaluation of many Green Lean wastes
Kaswan and Rathi (2019)	Manufacturing industry	Recognized GLSS enablers and modelling is done with the help of interpretive structural modeling (ISM) which methodically determines the relationship between these enablers. Further, Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC) analysis has been used to classify these enablers for better interpretation. The study exposes that twelve GLSS enablers hindering the implementation of this approach are recognized and modeled	The application model for the realization of GLSS in manufacturing at distinct phases of DMAIC methodology has not been reported
Sony and Naik (2020)	Mine industry	Presented a framework for implementing this strategy within the organization to attain the green goal through the DMAIC process of the five aspects of the environmental exhibition. In this paper, a case study approach is used to implement the GLSS framework to reduce the level of graphite and dust pollution in cast mines	The key limitation related to this study was that a single case study was predicted as being an execution framework. It grasps a substantial time for execution and analysis, taking into consideration various variables
Siegel <i>et al.</i> (2019)	Manufacturing SMEs	Proposed a conceptual framework for a collective	Six Sigma concepts were not incorporated

(continued)

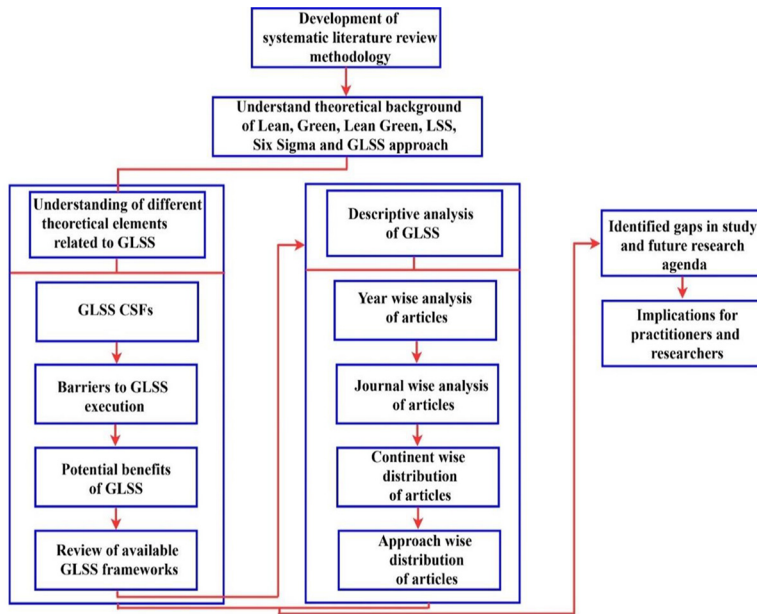
Authors, year	Sector	Major contribution	Limitations
		green lean approach and sustainability for small-medium enterprises. The result requires that the most general incitement to green lean implementation is a shortage of matrices and evaluation	for the minimization of variations in manufacturing operations
Hussain <i>et al.</i> (2019)	Construction industry	Identified barriers to the GLSS construction process through the literature survey and the opinion of the experts. Further, these barriers were authenticated by brainstorming sessions. The study reveals that there will be a reduction in wastage generation process variation and environmental impacts after implementing this strategy in the construction industry	The implications of this work may not be appropriate for other industries that may have other valid issues
Kaswan and Rath (2020)	Manufacturing industry	Proposed integrated and progress DMAIC-dependent GLSS framework. The proposed framework provides a pathway for GLSS implementation by a suitable preference for the project. The study exposes that many sustainability measures have been assessed with the help of unique GLSS indices and toolsets	The framework of GLSS has not been tested practically
Shokri and Li (2020)	Manufacturing industry	Implemented green strategy into LSS approach projects in manufacturing sectors. It also recognized under which circumstances the output of LSS projects with prudent benefits are more environmentally sound. This results in achieving greener, customized and economic-oriented outcomes	The present model is extremely distracted to describe the decision in LSS
Prashar (2020)	Pharmaceutical industry	Minimization in electricity utilization, minimization in the emission of tons of CO ₂ per kilowatt-hour of energy	The presented framework is probed by research actions within a single commercial element of a large multinational industry majority of drugs

(continued)

Table 3.

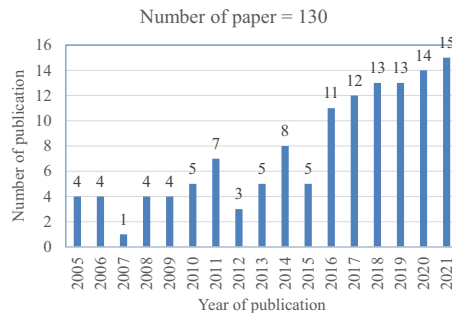
Authors, year	Sector	Major contribution	Limitations
Yadav <i>et al.</i> (2021)	Manufacturing industry	Presented integration and development of the GLSS framework in the manufacturing environment. Integration of the GLSS approach has been presented on intangible features like enablers, toolsets, etc. This article also presents a five-facet GLSS framework for an industrial organization to increase organizational sustainability. The major drawback of this study was that the GLSS framework had not been authenticated with the help of a case study	GLSS framework had not been authenticated with the help of a case study
Kaswan and Rathi (2020)	Manufacturing industry	Critically reviewed the GLSS strategy simultaneously with readiness measures, failure factors, integration and implementation of the framework. This study also presents a methodical GLSS framework with the related toolsets to encourage industrial managers and practitioners to execute this sustainable strategy	GLSS framework had not been probed practically
Gholami <i>et al.</i> (2021)	Chemical industry	Minimized consumption of chemicals and energy in the operations by 28% and 21%, cost saving in operations	The proposed framework had not considered the application of lean
Rathi <i>et al.</i> (2022a)	Manufacturing industry	Developed a framework for GLSS for capacity waste reduction in the fastening component industry	The framework was formed from the literature and consulted with the industrial personnel. Furthermore, no techniques and actions were dispensed to modify the level of the defect and societal sustainability of the considered industry

Table 3. Source: Authors' creation



Source: Author's creation

Figure 2.
Adopted research methodology

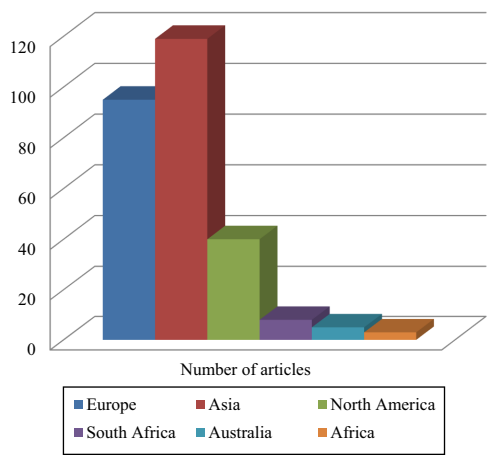


Source: Author's own creation

Figure 3.
Distribution of publications per year across the period studied

published throughout the previous span of the period. The manuscripts on Green, Lean and Six Sigma continuously increased after 2015. It is apparent from the graph that the greatest number of manuscripts were published in 2021, dispensing better evidence of research developed on current information. Then more manuscripts were published in 2020 and after that, more manuscripts were published in the year 2018 and 2019 on GLSS, respectively. A relatively less number of manuscripts were published in the year 2007 and 2012. Furthermore, the distribution of manuscripts of GLSS was found on seven continents of our world (Figure 4). Out of 270 research articles, 119 were contributed by Asia, followed by Europe and North America.

Figure 4.
Continent-wise
distribution of
publications



Source: Author's own creation

4.2 Categorization of manuscripts journal wise

To explore the literature in depth, further categorization of the article according to journal wise has been performed (Figure 5). It is observable that the *Journal of Cleaner Production* contributed to a large portion of the manuscripts (24) published in this field. This is maybe because of the way that most research papers talk about ecological issues in this journal and as such, hold a lot of pertinence toward this research study. International Journal of Lean Six Sigma (11) likewise dispenses a lot of manuscripts in this field. Then after that, research papers (9) were published in each international journal of Six Sigma and competitive advantage, *the International Journal of Quality and Reliability Engineering* and the *International Journal of Production Economics*, respectively. It can be assumed that research on the integration of GLSS is expected to be published in a variety of well-reputed journals.

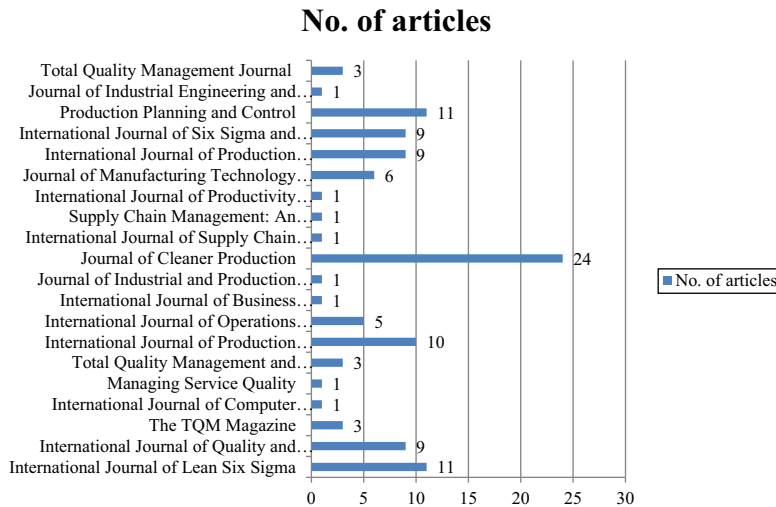
4.3 Approach-wise categorization of articles

Further, to explore the extent of articles according to different combinations of operational excellence approaches was performed (Figure 6). This leads to the exploration of the trending themes of the operational excellence approach.

The study reveals that 29.92% of manuscripts are published on LSS, 18.10% of research papers are published on Lean and Six Sigma separately, 17.48% of manuscripts are published on integrated Green-Lean strategy and 12.11% of the manuscripts are published on the integration of GLSS strategy. It is perceived that most of the research has been done in the field of LSS (27.92%) when contrasted with Green-Lean (17.48%). So, limited research has been carried out on integrating the GLSS (12.11%) approach, which requires the future direction and importance of the research work.

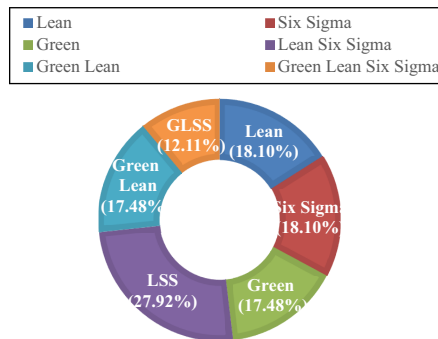
5. Identified research gaps and future scope of the research

In this review, the existing literature on GLSS published during the time of 2005 to 2021 is assessed to separate hypothetical components from fostering an integrated framework. The encouraging or adverse results on the environment because of GLSS execution cannot seem



Source: Author's creation

Figure 5.
Categorization of
manuscripts journal-
wise



Source: Author's creation

Figure 6.
Approach-wise
categorization of
articles

to be investigated in all industrial organizations. Hence, there is a requirement for the integration of similar approaches. The study reveals that research in the area of GLSS is in the increasing phase. To motivate researchers in the area of GLSS and provide appropriate directions, we feature the gaps in the existing literature for fostering the research plan. The analysis carried out gives numerous directions for future scope in the GLSS field.

5.1 Performance measurement system

In this review, this is tracked down that few kinds of research examined performance measurement, yet the performance measurement in Green, Lean and Six Sigma was analyzed separately. According to the sustainability perspective, there is an unavailability of a unified measurement and metrics system to evaluate the incorporated performance of these three approaches.

5.2 Integrated framework, model and methods

The corroborative interrelationship among GLSS has encouraged organizations to use three kinds of approaches to enhance their functional performance (EPA, 2003). Banawi and Bilec (2014) proposed a framework for incorporating three strategies for the construction sector to mitigate environmental effects. Cluzel *et al.* (2010) proposed an eco-plan strategy that intends to incorporate the GLSS approach for ecological evaluation and enhancement. The encouraging or adverse results on climate because of GLSS execution presently cannot seem to be investigated in all industrial organizations. According to Park and Linich (2008), “LSS can be a significant part of Green that assist any organization with boosting sustainable performance.” The study reveals that there is a lack of research in the area of integration of three approaches just as various issues that are general to the vast majority of business models. These frameworks allude to the requirement of robust leadership, support of higher management and involvement of every worker for continuous enhancement exertion to provide top-quality performance (Pampanelli *et al.*, 2014). Everyone’s methods/framework depend on the organizational culture of TQM.

5.3 Application of Green Lean Six Sigma in small and medium enterprises

SMEs are considered the backbone of any nation’s economy. In general, this sector accounts for the most significant portion of established enterprises (Saleh and Ndubisi, 2006). India is one of the developing nations whose economy majorly depends on the SME sector (Siegel *et al.*, 2019). Despite its great role in economic growth, it faces dynamic environmental, competitiveness and continuous improvement (Gandhi *et al.*, 2018). SMEs are incredibly accountable for carbon emissions (M. Singh *et al.*, 2021). This sector is responsible for 70% of industrial pollution resulting in \$32bn in environmental costs (NPC, 2013; MoEF, 2012). It also consumes 6% of total energy consumption (Haeri and Rezaei, 2019). SMEs are the primary source of CO₂ emission (117.98 million tons/year) in India (Ministry of the Environment, 2020; Krolczyk *et al.*, 2020).

5.4 Service sector

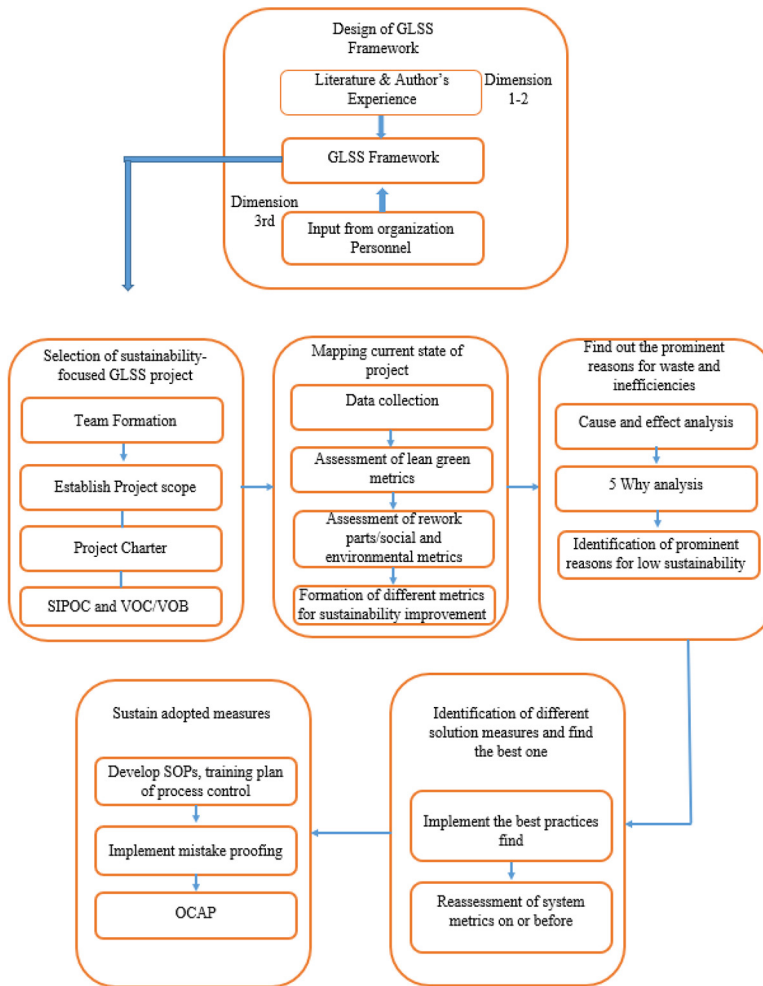
The potential of GLSS has not been explored to its full potential in the service sector. As per Vargo and Lusch (2008), the service sector is a critical portion of our economy that could be observed as a significant under-investigated influent.

5.5 Societal aspect

Integration of GLSS methodologies results from societal change that should include the shareholders. The review recognizes that the interrelationship between these three approaches and societal performance is not completely examined in academic research. Also, social performance (safety, health, staff assurance, expertise, etc.) appears to be obscure. Consequently, there is a requirement to concentrate on the human side more extensively and take a look at the administrative difficulties of dispatching, driving and making persons for GLSS exertion.

6. Proposed framework for Green Lean Six Sigma execution

The proposed framework of GLSS; leads to improved organizational sustainability by reducing defects, wastes and environmental emissions (Figure 7). The GLSS framework evolved dependent on three design dimensions. The first design dimension comprised the activity of studying the characteristics, the main cause for development and appropriateness of the several GLSS execution frameworks pointed up in the last section.



Source: Author's creation

Figure 7.
Proposed framework
and adopted
methodology

This secured the incorporation of the most current and specific conceptual knowledge into the developed GLSS framework. The second design dimension incorporated using the substantial theoretical and industrial revel of the authors as specialists, industrial practitioners and academic researchers to help the development of the proposed framework. [Garza-Reyes *et al.* \(2016\)](#) recommend that the experience of practitioners performs a crucial role while developing conceptual frameworks which are needed to be implemented in the industry.

Finally, the third design dimension incorporated the consideration of appropriate inputs from the industry. Thus, the authors discussed this with a team of experts. Consequently, 40 experts were recognized from several departments of the selected industry, other industries and academicians. From this group, 18 industrial experts agreed to dispense their feedback

about the GLSS framework. The expert panel comprised general managers, senior managers, master black belts, project leaders from the selected industry and experts from an academic background. Each expert that was included in the panel had more than 18 years of industrial and academic experience. The experts dispensed valuable feedback and criticism to improve the applicability and maturity of the GLSS framework. Afterward, the developed framework was probed in a leading manufacturing industry. The purpose was to gather appropriate observations, evaluate weaknesses and regulate the framework.

The proposed framework was developed to inscribe problems associated with ecological and quality measures of projects and enhance the functional dynamics of industrial sectors. Every step of the attainment of the GLSS framework has several activities that minimize waste and related ecological impacts. So, the current study's unique contribution lies in supporting industrial sectors to compute several functional, environmental and societal measures and dispense ways to enhance and sustain the same for improved organization competitiveness. The conceptual facets of the developed GLSS framework are discussed below:

Step 1: This step of the developed framework is concerned with recognizing and delineating the adopted project. The scope of the project is considered to explore ecological, social and quality implications. The requirements, preferences and presumptions of the business and customers are clearly stated in terms of VOB and VOC to recognize the expectations from the product being manufactured. This has been recognized from VOB and VOC analysis that the firm needed high-level customer satisfaction, capacity usage and worker engagement while customers want high-specification eco-friendly products at a reasonable cost. In this step, the subsequent process of manufacturing, SIPOC diagram and project charter dispenses a complete understanding of several aspects of the adopted GLSS project.

Step 2: In this step, data collection was carried out to represent the current state of the system and data corresponding to defects and inefficiencies. Moreover, EVSM analysis was used to evaluate the current state of the project concerned to lead time, raw material consumption, water consumption, etc. LCA was also used in this phase of the GLSS framework to estimate the current environmental impacts of the process. The data prevails to rework was also gathered to find out the shop's critical to rework problems.

Step 3: This phase focuses on recognizing the root causes of waste and inspecting the problems and process inefficiencies. Based on the measure phase, reasons for inefficient material handling, rework, low environmental performance and enhancement in societal sustainability are recognized. When the potential causes are recognized, then the search is dispersed to obtain crucial contributors to waste and inefficiencies.

Step 4: In this phase, several solutions are recommended and the best solutions are recognized and implemented to mitigate the root causes of waste and inefficiencies. Each suggested solution has been executed in such a way that an appropriate recording can be done to compare with previous results. The training has been provided to employees and managers of the organization from time to time for the effective execution of the GLSS approach.

Step 5: In this step of GLSS implementation, enhancements obtained are registered to sustain the improvement actions. Now, the enhanced process is handed over to the process owner along with the whole procedure for sustaining the gains. This step confirms that gains attained from the enhancements made are sustained after the accomplishment of the GLSS project. In the beginning, it is imperative to document and regulate the process to represent a perfect image of the improvements made and how to maintain these improvements.

6.1 Summary of the review

The objective of this review is to explore different aspects of the GLSS approach, application status and potential benefits from a comprehensive review of the literature and provides an avenue for future research work. This review proposes a five-facet GLSS framework to minimize overall defects and environmental impacts simultaneously to enhance the functional and environmental performance of the organization. The study depicts that GLSS implementation is increasing yearly, leading to considerable improvement in all dimensions of sustainability. Enablers, barriers, tools and potential benefits that foster the execution of GLSS in industrial organizations are also identified based on a systematic review of the literature. The study's uniqueness lies in that this study is the first of its kind that depicts the execution status of GLSS, and its different facets explore different available frameworks and provide avenues for potential research in this area for possible researchers and practitioners. The implementation of the proposed framework assisted in enhancing the sigma level of the case industry and also minimized the overall environmental impacts. The contribution of the present review pretends two-fold, first, the GLSS framework has been suggested to direct conducting of the activities of implementation of this program. The presented framework dispenses a prospect to the industrial sectors to enhance ecological wastes, improved capacity usage and handling of items, along with enhancement in social subtleties by the deployment of tools like LCA, SLCA, EVSM, Kaizen, etc. Second, this work exhibits the empirical benefits of using the projected GLSS by its effective execution framework in an industrial environment by methodical insertion of Green technology, Lean and Six Sigma tools. The present review accommodated the organization to understand its present level of environmental effects and aided it to detect further minimizing CO₂ emissions by the integration of more green technology measures. This framework also had a constructive impact on societal significance as enhancements were perceived to relate to the health of humans (as an outcome of minimized ecological effects) and shopfloor safety (after the deportment of the 7S). The industrial sectors were also encouraged to share their profit in corporate social responsibility activities.

7. Conclusions and limitations of the research

Ecological and societal facets have become tactical needs for companies and customary preferences of productivity and profitability to sustain in this competitive market. GLSS has been demonstrated to be one of those incorporated strategies that need additional investigation and further exploration. The current manuscripts dispense a similar effort of investigating different perceptions of the GLSS area. The several philosophies used by academic researchers and experts have been clarified, and gaps for future research are distinguished. In all, 140 research papers from the period from 2005 to 2021 were taken into consideration for the literature review.

In the current study, the study of manuscripts was done dependent on: CSFs for the implementation of the GLSS approach, performance improvement barriers, frameworks/models/methods of GLSS. The year of journals and publication journals were also taken into consideration for the analysis of the paper. The analysis of these distinct classifications gives a better comprehension of the GLSS field and upgrades the knowledge base. The study reveals that 29.92% of manuscripts are published on LSS, 18.10% of research papers are published on Lean and Six Sigma separately, 17.48% of manuscripts are published on the integrated Green-Lean strategy and 12.11% of the manuscripts are published on the integration of GLSS strategy. It is perceived that most of the research has been carried out in the field of LSS (27.92%) when contrasted with Green-Lean (17.48%). So, limited research has been done on the integration of the GLSS (12.11%) approach, which requires the future direction and application of the research work. The categorization of chosen manuscripts also investigates several future

research directions for academic researchers and practitioners. This shows that research in the area of GLSS is in the increasing phase.

The present study is the first of its kind that provides a better understanding of different theoretical elements related to the GLSS approach. This study provides different theoretical elements like GLSS CSFs, barriers to GLSS implementation, potential benefits of this approach and a review of available GLSS frameworks. The existing literature lacks any evidence about the different theoretical elements related to this approach for effective implementation. Thereafter, a descriptive analysis of published articles has been carried out. From the comprehensive review of the articles, potential research gaps have been identified for fostering the research plan. The analysis carried out provides several directions for future scope in the GLSS field. The current research presents both theoretical and practical implications for practitioners and researchers. More research should be started in developing countries like India these nations to recognize GLSS barriers for the developing nations and outline to eliminate these barriers.

The present study might have some drawbacks because of the scarcity of accessibility of pertinent and adequate literature on the subject matter. However, restricted data is accessible about linking GLSS techniques in industrial sectors. The research is based on a survey analysis that may not provide accurate results. In this study, there are some leading journals were considered for analysis. In the literature, only papers, papers in the press, review papers and quality papers like international conference papers and conference review papers are taken into consideration to maintain the quality of the manuscript. Online reports, thesis and books are excluded during the choice of research papers; appropriately, it is well might be probable that some of the research manuscripts might have been left remaining to cover in this literature review.

7.1 Theoretical and practical implications

To assist the industrial practitioners to use three approaches instantaneously in an environment where linking among GLSS methods in manufacturing sectors has not been instituted. Thus, instantaneously employment of these three approaches encourages the manufacturing industries to improve their functional and environmental performance. This review also encourages ecologists and entrepreneurs to initiate sustainable industrial methods like GLSS that reduce ecological damage by recommending the 5R technique. Furthermore, the academic audience can use these bits of knowledge to grow their comprehension of the ideas and might be urged to explore to apportion a specific and explicit hypothesis on the GLSS approach. Finally, insights on GLSS grey areas will enable project managers and practitioners to develop a GLSS framework for improved operational and environmental efficacy. Society will also be benefitted from the current study by getting eco-friendly products at reasonable costs.

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