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

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Abstract

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

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

Findings: The 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.

Originality: The study's uniqueness lies in that 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

1. Introduction

Over the last 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 employ 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 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 & 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 dispense 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 utilized 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 to 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 approach, respectively.

2.1 Literature Search Methodology

To do a literature review, the authors have followed the systematic literature review (SLR) methodology. SLR provides an explicit view of the literature review and the uniqueness of the study. 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, Lean Six Sigma, Green Lean Six Sigma, Sustainability, barriers, framework, manufacturing, etc. To select pertinent articles related to the study, firstly, 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 identified 140 articles. Once the 140 articles have been identified, the authors critically investigate all the articles to identify different facets related to the Green Lean Six Sigma implementation and other hidden areas that are not explored to date. Figure 1 depicts the systematic literature review methodology.

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 Rathi, 2021b; Galeazzo et al., 2014). In manufacturing sectors as well as for the service sectors, lean strategy has been demonstrated a significant methodology for the development of an organization (Raci & Shankar, 2005). Rathi 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 employed on the participation of employees through utilizing tools and methods like Kaizen, Kanban, 5S, poka-yoke, and value stream mapping (VSM) (M. Singh et al., 2021; Jurado and Fuentes, 2014).

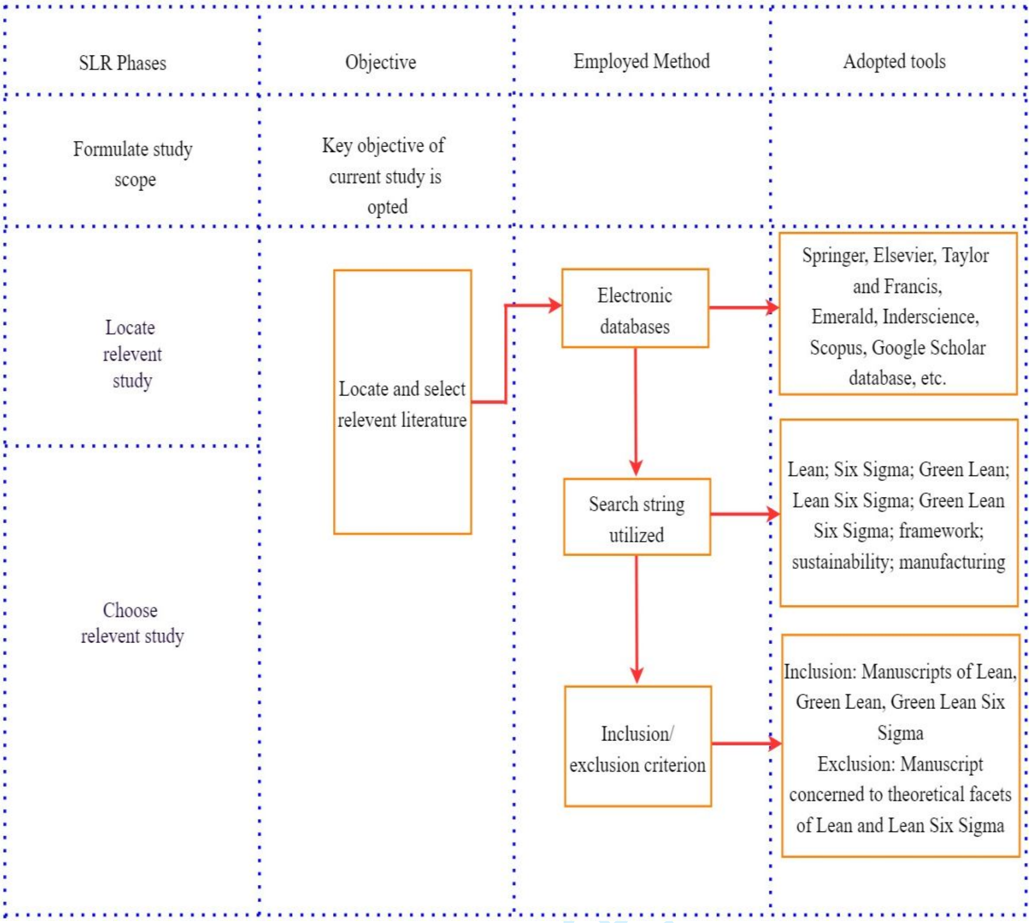

Fig. 1. Systematic literature review methodology

2.3 Green technology

Green technology is employed to minimize pollution and waste by reducing natural resource use. This concept also uses the 3'R technique (reduce, reuse, 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 employed on discipline and appropriate training to the employees by utilizing various practices such as waste recycling, life cycle assessment (LCA), green designing and packing, etc. (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. (Prasad et al., 2016) ecological strategies in the form of eco-labeling, environmental management system (EMS), and ecological regulations have created a huge demand for green manufacturing in industrial sectors. Karuppiah et al. (2020) identified twenty-five barriers to the execution of GM in Indian 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 wastes is that first is about non-value-added activities, and the second is about needless utilization of water, electricity, and natural assets (Mollenkopf et al., 2010; Ferreira et al., 2020). Gadekar, A. and Gadekar (2014) introduced an incorporated framework for these practices for attaining both financial and ecological sustainable performance in an organization. Pampanelli et al. (2014) believed that the green and lean concept could decrease resource utilization from 40 to 60 percent 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 greenhouse gas 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 employ 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 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 on the status of SS execution in SMEs of United Kingdom. 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 utilized 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 employed the LSS philosophy in service areas like retail banks and acquired a profit of INR 1.6m.

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 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 systematic literature review (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 employed.

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 employed 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 employed 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 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) 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, inspecting 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 (2020b) 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 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 GLSS strategy

Critical success factors are imperative for implementing any type of strategy in the manufacturing sector (Rungasamy et al., 2002).

Habidin and Yusof (2013) recognized the following critical success factors to execute LSS:

(1) Leadership
(2) Structured improvement process
(3) Quality information and analysis
(4) Supplier relationship
(5) Customer focus
(6) Focus on metric

Cherrafi et al. (2017) recognized the following critical success factors to execute the GLSS strategy effectively:

(1) Organizational Readiness to execute GLSS approach

(2) The project is chosen, and prioritization

(3) A commitment of higher management and Employees

(4) Communication

(5) Resource and skills to facilitate execution

M. Singh & Rathi (2019) identified 16 success factors to implement LSS strategy in MSMEs (Micro-small and medium enterprises). Out of 16 critical success factors, 10 CFs are prioritized using BWM (Best Worst Method). Raval et al. (2021) identified 10 CFs for effective implementation of LSS strategy in manufacturing sectors. The study reveals that top management is the most critical success factor and should execute in a step-wise methodology under the drawbacks of available resources.

2.7.2 Barriers and drivers for integration of GLSS 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 & 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 systematic literature review (SLR). Then, they were validated through ISM and MICMAC analysis. Hussain et al. (2019) recognized twenty-four barriers in the construction sector. Then, the ISM technique was employed to establish the relationship between these barriers. C. Singh et al. (2021) identified twelve 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. Further, 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 to eliminate waste (Langenwalter, 2006; G. Yadav and Desai, 2017). These tools and techniques of LSS include LCA, JIT, TPM, Kaizen, VSM, 5S, C&E diagram, QFD, etc. These tools have been modified and expanded to gain more ecological and societal development (Kaswan and Rathi, 2020a). But these tools and techniques should be painstakingly chosen and should be fitted with the manufacturing sector's set-up (EPA, 2003). Table 1 depicts the effect of distinct LSS tools on the environment.

Table 1. Effect of distinct LSS tools on environment concern

LSS Tools	Obtained Environmental Benefits	References
Life Cycle Assessment	LCA technique will facilitate the organizations to search for the most accessible life cycles which are helpful for mitigation of harmful impacts	Paolotti et al. (2016); Kamei et al. (2013); Kaswan and Rathi (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)
Value Stream Mapping	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	Bae et al. (2007); Wilson (2010); Costa et al. (2018)

	as systematization has been retained in the industries.	
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.	Loon et al. (2014); Kennet (2008); Rios et al. (2019)
Quality Function Deployment (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)

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 depicts the interpretation of framework, models, and methods and Table 3 depicts prominent research regarding Green Lean Six Sigma in different industries.

Table 2. Interpretation of frameworks, models, and methods

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 et al. (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 restricted only to service sectors.
Subrata Talapatra (2019)	Green, Lean, and Six Sigma	Proposed and implemented framework	Presented and executed GLSS framework for 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 Rathi (2020b)	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 major drawback of the current study was that the framework of GLS has not been tested practically.

			The research work exhibits that several sustainability actions had been assessed with the assistance of exclusive GLSS indices and a toolset.	
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 et al. (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.

Table 3. depicts prominent research regarding Green Lean Six Sigma in different industries

Authors, Year	Sector	Major contribution	Limitations
Izzaida et al. (2013)	Automotive Industry	Established the interrelationship between Green Lean Six Sigma (GLS) and Management Innovation (MI). It also explores how GLS 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 Systematic Literature Review (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 application computation tools in various phases.
Cherrafi et al. (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 reduce from 20 to 40% and 7-12%, respectively, after executing this approach.	This framework was that sensitive operations may be elaborated to enhance by this methodology.

Mangla et al. (2017)	Automobile Industry	Recognized barriers in GLS 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 employed to initiate a hierarchical model of these barriers in implementing the GLSPD process in the automobile sector.	GLS framework was that it did not analyze properly.
Ruben et al. (2018)	Manufacturing Industry	Represented the effective execution of the LSS framework with environmental considerations to pledge the minimization in 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 employed only automotive component organizations and definite manufacturing sectors working with analogous manufacturing operations.
Powell et al. (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 et al. (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 successfully related greening to lean abilities may reduce environmental impacts within the hospitals.	The presented frameworked had not been tested practically.
Sreedharan et al. (2018)	Public sector	Dispensed the GLS modal for public sectors. This modal improves the efficient brilliance of public sector assistance like telecommunication, construction, and health care. GLS 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 GLS enablers and modeling is done with the help of Interpretive Structural Modelling (ISM) and methodically determines the relationship between these enablers. Further, Impact Matrix Cross-Reference Multiplication Applied to a Classification (MICMAC) analysis has been utilized to classify these enablers for better interpretation. The study exposes that twelve GLS enablers hindering the implementation of this approach are recognized and modeled.	The application model for the realisation 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 employed to implement the GLS framework to reduce the level of graphite and dust pollution in cast mines.	The key limitation related with 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 et al. (2019)	Manufacturing SMEs	Proposed a conceptual framework for a collective 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.	Six Sigma concepts were not incorporated for the minimization of variations in the manufacturing operations.

Hussain et al. (2019)	Construction Industry	Identified barriers to the GLS 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 Rathi (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 GLS indices and toolsets.	The framework of GLS has not been tested practically.
Shokri and Li (2020)	Manufacturing Industry	Implemented green strategy into lean six sigma 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 CO2 per kilowatt-hour of energy	The presented framework is probed by research actions within a single commercial element of a large multinational industry majority drugs.
Yadav et al. (2021)	Manufacturing Industry	Presented integrated and developing 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 et al. (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 et al. (2022a)	Manufacturing Industry	Developed a framework for GLSS for capacity waste reduction in the fastening component industry.	The framework formed from the literature and to consult with the industrial personnel. Furthermore no techniques and actions were dispensed to modify defects level, societal sustainability of considered industry.

2.8 The 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 moderates 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 & 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 & 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 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 systematic literature review (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 & Rathi, 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. 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 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. Figure 3 depicts the adopted research methodology.

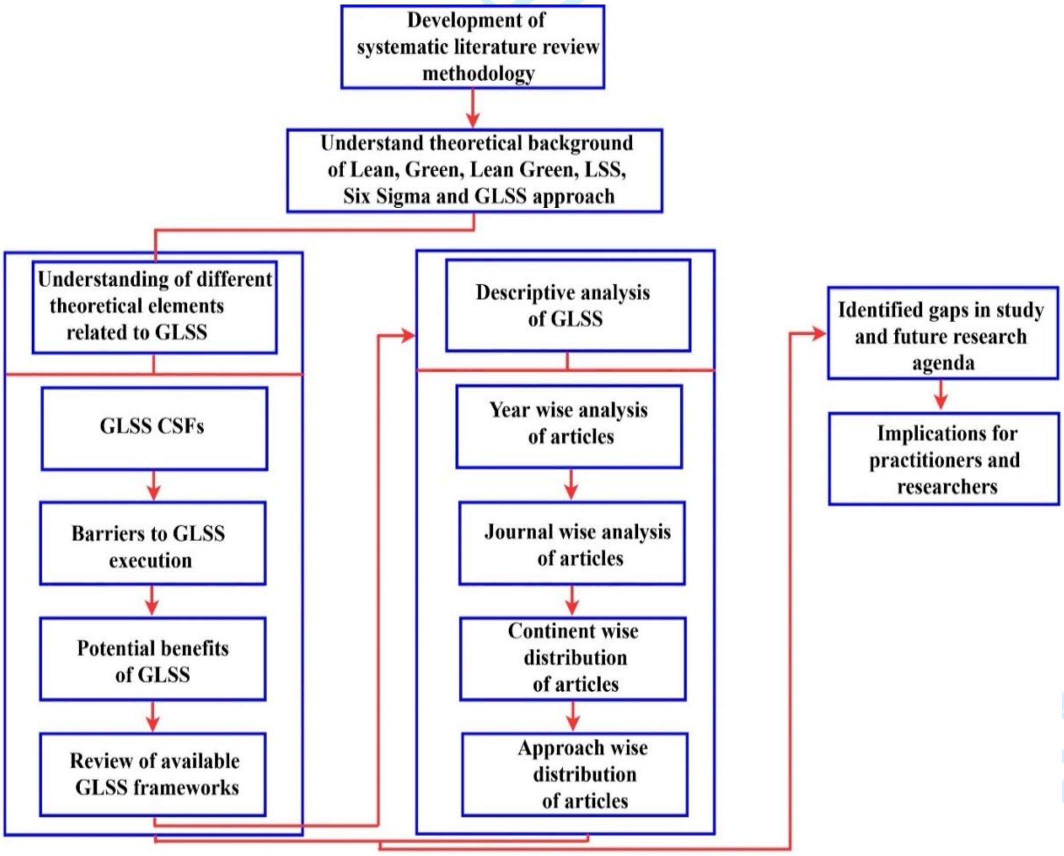

Fig. 3. Adopted research methodology

4. Descriptive Analysis

4.1 Categorization of manuscripts according to the year of publication

Figure 4 exhibits the categorization of manuscripts according to the year of publication over the period from 2005 to 2021 in which 140 articles were studied. This was reorganized from the studies of (Parmar & Desai, 2020) and (Gaikwad & 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 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. Out of 270 research articles, 119 were contributed by Asia, followed by Europe and North America. Figure 5 outlines the continent-wise distribution of publications.

4.2 Categorization of manuscripts journal wise

Figure 6 shows the categorization of several manuscripts in the journal publications. 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 towards 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, *International Journal of Quality and Reliability Engineering*, and *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.

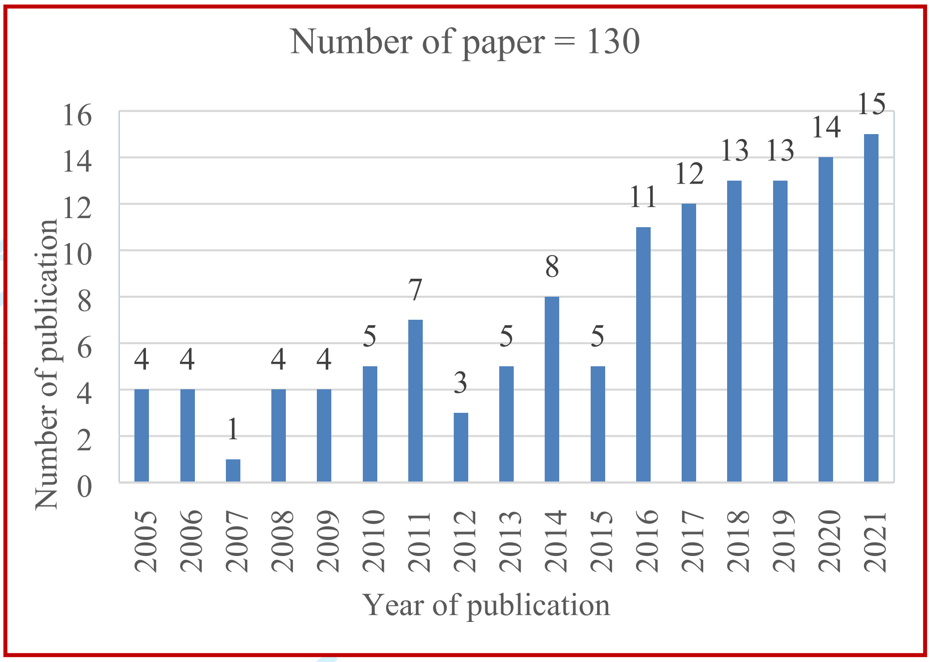

Fig. 4. Distribution of publications per year across the period studied

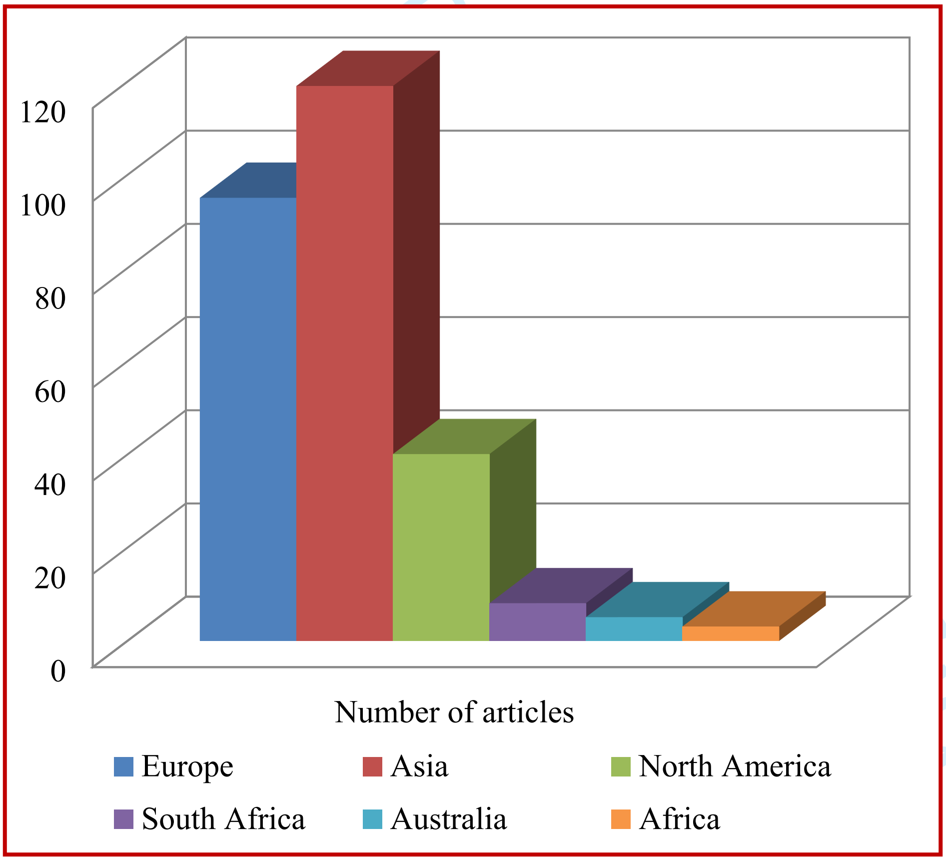

Fig. 5. Continent wise distribution of publications

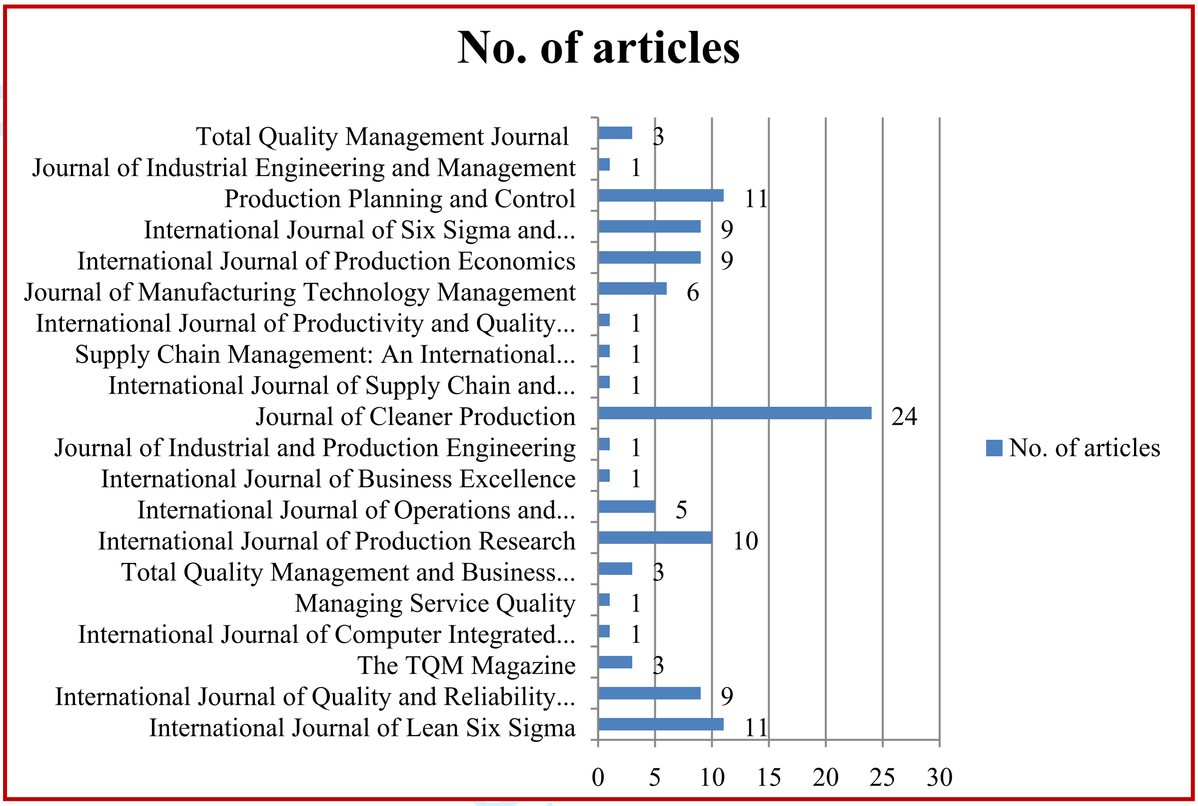

Fig. 6. Categorization of manuscripts journal wise

4.3 Approach-wise categorization of articles

Figure 7 illustrates the distribution of published papers for Green, Lean and Six Sigma separately and incorporated strategies of LSS, Green-Lean, and GLSS.

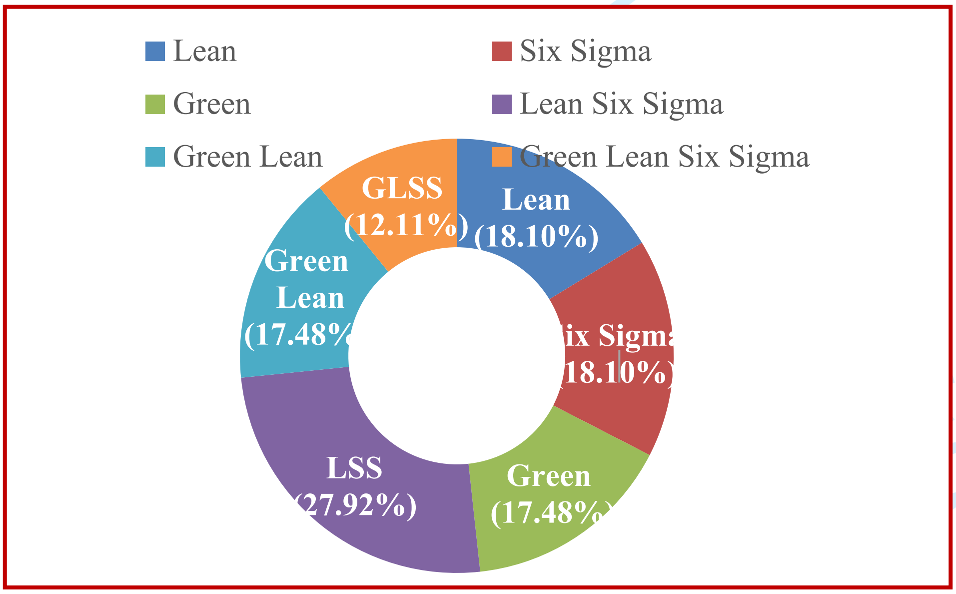

Fig. 7. Approach-wise categorization of articles

The study reveals that 29.92 percent 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. Referring to Figure 4, 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 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 utilize 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 GLSS in SMEs

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 percent of industrial pollution resulting in $32 billion in environmental costs (NPC, 2013; MoEF, 2012). It also consumes 6 percent of total energy consumption (Haeri & Rezaei, 2019). SMEs are the primary source of CO_2 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 GLSS execution

Figure 8 depicts the GLSS execution framework proposed by the authors for minimizing defects and environmental impacts for the considered manufacturing organization. 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.

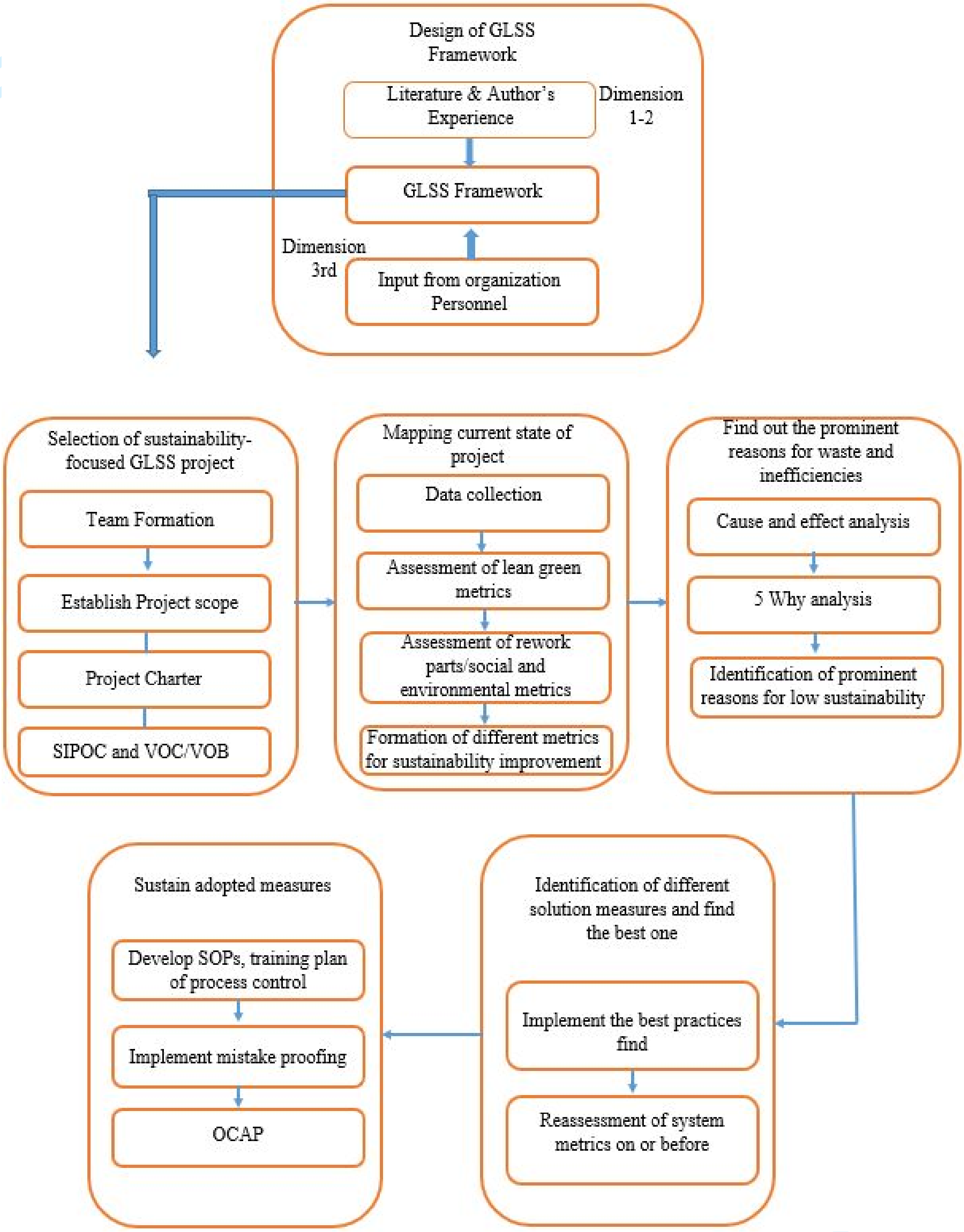

Fig.8: Proposed framework and adopted methodology

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 experience of practitioners performs a crucial role while developing conceptual frameworks which are needed to be implemented in the industry.

Lastly, 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 eighteen 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 employed to evaluate the current state of the project concerned to lead time, raw material consumption, water consumption, etc. LCA was also utilized 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 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.

Summary of the review

The objective of this review is to explore different aspects of the Green Lean Six Sigma 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 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 in conducting 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 CO_2 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 (CSR) 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 literature review.

In the current study, the study of manuscripts was done dependent on: critical success factors for the implementation of the GLSS approach, performance improvement barriers, frameworks/models/methods of GLSS. 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 critical success factors (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. Although, 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.

Theoretical and practical Implications

To assist the industrial practitioners to employ three approaches instantaneously in an environment when 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 5'R technique. Furthermore, the academic audience can employ 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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