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COMPUTING THE INTENSITY OF SUSTAINABLE LEAN SIX SIGMA ENABLERS TO ENHANCE ITS ADOPTION: AN INDIAN CONTEXT STUDY

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Abstract

It has been a common observation among the manufacturing organisations over the past decade that the estimated financial performance can be achieved when the organisation primarily focuses on the continuous improvement process and simultaneously consider the environmental and societal parts as a whole within the product development process. In this regard, sustainable lean six sigma (SLSS) has emerged as the most prominent solution to the above addressed context. Although, over the globe several manufacturing organisations in the emerging economies have reported that the SLSS adoption remains limited due to the complex interplay of multiple organisational, managerial, technological, and sustainability-related factors. Many research studies in literature also revealed that the lack of awareness of SLSS enablers has been a common reason behind its adoption failures. The present study helps to fulfil this gap an identifies the set of most critical SLSS enablers that influences its adoption. An exhaustive literature review is conducted in order to identify the key set of SLSS enablers that strategically fit into manufacturing environment. The identified set twenty-five critical enablers are further analysed through fuzzy analytical hierarchy process (FAHP) to obtain the enablers weights. An expert team is constituted to capture the multi-criteria decision-making inputs for the fuzzy AHP approach. The results reveal that strategic and managerial factors—such as top management commitment, organisational culture, employee training and competency development, and availability of resources—emerge as the most influential enablers. The study provides strong theoretical contributions by expanding SLSS literature and presents the SLSS adoption framework with the intensity of enablers associated in the adoption process. The study findings will be beneficial for both the researchers and practitioners working the domain of SLSS.

Keywords: Sustainable Lean Six Sigma, Enabler Prioritization, Fuzzy AHP, Manufacturing Industry, Lean Practices, Six Sigma, Decision Making.

1. INTRODUCTION

It has been globally observed that Lean Six Sigma (LSS) has gained popularity among the developed economies, and it has turned up as one of the most prominent philosophies for practitioners across the manufacturing and service sectors (Henao et al., 2021). It has significantly helped them to improve their productivity and has gained huge popularity among practitioners who are continuously working to fulfil the goals aligned with the vision and mission of their organisations. This concept primarily focuses on the waste reduction aspect, which is the backbone of lean practices, as in this concept it further collects the crux of the six-sigma aspect to improve the product quality, as this specifically helps them to achieve operational excellence within the organisation. This is the specific concept that helps in improving the quality cycle times productivity and also assist in eliminating the

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non-value-added activities within the system. However, this has been noticed that among the global pressure to achieve the profits and gain the financial performance within the system has specifically increase the pressure among the practitioners and managers, and it has also increased the pressure for inclusion of environmental concerns within the production system. Hence, along with the integration of lean concept with Six Sigma the practitioners are bound to include the sustainability and environmental aspect along with it. Accordingly, the concept of Sustainable Lane Six Sigma (SLSS) has gained the popularity among the manufacturing organisations and service sectors and several researchers and practitioners in literature have also reported the improved organisational performance in their system specially among the organisations that falls under the developed economies (Bhatia and Kumar 2023).

SLSS takes the quality improvement aspect on to the next level whereas the traditional LSS framework has an inclusion of environmental and social responsibility concept that gets aligned with the process improvement initiatives (Chen and Raza 2021). This integration of sustainability concept with the existing in six sigma methodologies specifically focuses to fulfil the current market meets by taking care of the environment without any compromise with the product quality and cost so that the global demand of the product and the market competition is being handled simultaneously and it further boost the applicability and sustainability of the organisation on the global platform. This integration of environmental concept not only focuses on full feeling the global market meets but it also helps in completing the customer expectations based on the future generation requirements and its random considerations. In specific business perspective, the organisations working in the product development stages should not only focus on reducing the production costs and improvement in quality to achieve the operational performance but they should also focus on the environmental aspects to ensure that the final developed product has inclusion of environmentally friendly working, and less carbon footprint so that there is improved operational efficiency of the entire system. Once, the sustainability concept is integrated with the lean and Six Sigma concept then it automatically takes care of all the three important aspect that includes economic, environment, and social concerns in order to achieve the overall sustainability context (Chauhan et al. 2022).

Although, it has been observed that the SLSS concept has gained significant success among the manufacturing organisations in the developed economies due to the availability of Advanced technology setups, well-streamlined production system, awareness among the practitioners and managers for consideration of environmental aspects. However, on the other hand when the same concept is compared among the manufacturing organisations of the developing economies then the adoption rate of SLSS is very poor (Iqbal and Qureshi, 2021). Many researchers in literature have reported that the organisations of developing economies the awareness of environmental concern, resulting the focus of the manufacturing organisations of the developing economies to remain till elimination of non-value-added waste and improving the product quality. Their focus towards consideration of environmental factors remains under the least priority section. It is also observed that the organisations remain unaware about the different

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enablers that actually helps in the adoption of SLSS within the manufacturing organisations. Hence, when it comes to the consideration of SLSS in enablers, then the organisations must specifically focus on not only the external factors influencing the SLSS adoption but also the Inti internal factors which strongly affects the adoption rate. The inclusion of internal factors supporting the adoption of SLSS is taken into consideration then the organisation can easily integrate the sustainability driven improvement initiative along with the strategies of the organisation Saint with its goals for achieving the desired financial and operational performance of the entire system. When it comes to the penetration of enables influencing SLSS adoption within the manufacturing system it is important to critically identify the key enablers that are specifically responsible under the manufacturing environment and also prioritise those enablers so that the managers and practitioners among those manufacturing concerns can develop the effective strategies and road map for successful SLSS adoption (Gowda and Chandrashekhar, 2024).

This has been observed in the existing literature that there are several studies which have focus on identification of enablers for the stand-alone lean concept, six sigma approaches, and sustainability individually in context to the manufacturing organisations (Nasser et al., 2023). However, the studies reporting the enablers of integrated SLSS concept have rarely captured in Literature. This is very important aspect to note that them exist a strong need to identify such factors that directly focuses and has influence on SLSS adoption in the manufacturing concern. Although, a few studies in literature have dedicatedly worked on the identification of SLSS enablers that actually influence its adoption, but in those studies, there is no representation about the influence of those SLSS enables in its adoption process (Silva et al., 2022). This creates a confusion among the managers and practitioners who are working towards the adoption process. This is important to note that the persons involved in the SLSS adoption process should be very clear to understand the intensity of influence of SLSS adoption enablers specifically because not every enabler possess the same intensity of influence. Every enabler requires a separate level of attention during the implementation process. Similarly, the researchers have also reported that the absence of those prioritization studies has been a major of concern in the SLSS literature (Ferreira et al., 2021). More number of studies focusing on the road map of SLSS implementation, prioritisation techniques and strong industrial focus towards sustainability adoption will help in implementing and adopting SLSS effectively in the manufacturing organisations. In actual practice, the decision-making team involved in the SLSS adoption process, needs to put a strong attention towards the required resources the financial budget allocation, the specific awareness programs, improvement in technology setups, and developing a culture towards environmental concept adoption (Khan and Yu, 2023).

In this type of scenario, where the organisations and the associated managers involved in the adoption process need to identify and develop an analytical framework which can help to prioritise the identified SLSS enablers, the existence of MCDM techniques plays a very important role in this context (Mardi et al, 2024). To analyse the SLSS enablers, the MCDM offers a large number of decision-making approaches which can help to identify the intensity of the selected enables through a systematic analytical approach.

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Among these techniques, fuzzy analytical hierarchy process (FAHP), has turned out as an important MCDM approach which can handle the linguistic judgements, ambiguity among the judgements, subjective assessments, and also the biasness among the experts while giving their judgments. It is further observed, that the integrated fuzzy AHP approach offers a large number of benefits when it is compared with the traditional AHP process. This benefit offers more flexibility because the exports use triangular numbers comparison while capturing the input data for the analysis purpose. This Increases to achieve more realistic and precise perceptions of the experts involved in collecting the inputs for the analysis of MCDM approaches (Dhingra and Garg, 2024). This appears to be a more important approach when it is essential for the manufacturing organisations working under the developing economy concerns and focuses on the sustainability-oriented initiatives to achieve the desired organisation performance (Kumar and Singh, 2022).

Hence, based on the above requirement of identification and analyse of SLSS enablers, this research work utilises the fuzzy AHP to identify and analyse the key set of 25 critical SLSS enablers that can actually possess strong influence during the adoption process. The enablers selected for the study where screw tonight from the existing literature studies available in Literature. The studies specifically focus on the SLSS frameworks, the best industry practices which are required to maintain this standard sustainability norms among the system. The enablers are categorised into five major groups: (1) Strategic and Policy-Oriented, (2) Managerial and Human Capital, (3) Process Optimisation, (4) Technology and Digital Integration, and (5) Organisational and Supply Chain Capability. This categorization will help the researchers and practitioners working in the area of SLSS adoption to work deeply by diving into the sustainability concepts involved in the adoption process. Based on the above discussion, following objectives are defined for this study.

- To identify a comprehensive set of enablers that support the successful adoption of Sustainable Lean Six Sigma in manufacturing industries.
- To compute the weights and prioritise the Sustainable Lean Six Sigma enablers, identifying the most influential factors that drive effective implementation.

The managers and practitioners working on the strategic and policy-oriented enablers should have a deep focus on a lining the organisational objectives and the leadership of the management synchronised with the regulatory compliance and insurance the sustainability aspect inclusion by keeping customer focus as a key objective. On a similar note, the managerial and human capital enables should have a deep emphasize on the employee work capability, SLSS Training module, the collaboration of define the activities within the entire system. The process optimisation specifically includes the removal of non-value-added activities, reduction of waste, standardisation of processes, quality control, and an appropriate alignment of lean tool set defined in the existing LSS frameworks reported in the existing literature studies. The technology and digital integration enable should have a focus on enhancing the industry 4.0 associated practices, the smart factory adoption, real time monitoring of the activities within the entire

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system, and real time decision making to ensure the efficient sustainability adoption within the system. The organisational and supply chain enables has a primary objective to deal with the green design, sustainable procurement, collaboration among the suppliers and the integration of entire sustainable supply chain management along with the eco-design within the system.

Accordingly, it is important to analyse the enables falling under these five major categories define for the study. In several situations, as reported in the existing literature the manufacturing organisations dealing with the SLSS adoption possess less clarity about the intensity of influence of the selected SLSS enablers. Such scenarios, might lead to SLSS adoption failures (Bansal et al. 2022). To overcome such situations the management involved in the SLSS adoption process should recognise the critical enables that are aligned with the continuous improvement and spreading the awareness about the latest technology involved in order to automatic the entire production system but also build a strong connection between not only the inbound and outbound logistic activities but also develop a strong supplier collaboration in order to achieve the organisational goals effectively which can finally lead to improve the organisational performance. It is also important to note if the regulatory compliance is associated with the sustainability adoption are taken into consideration, then the industries can fulfil the customer-oriented product readiness and can with stand the global market competition (Dubey et al., 2021).

2. LITERATURE REVIEW

Several studies in Literature have recently reported that over the past decade the manufacturing organisations in both developed and developing economies have started integrating sustainability into their operational activities so as to improve their organisational performance and simultaneously achieving the sustainability goals (Vinodh and Kariappa, 2013). It is well known that the LSS concept is a structured design that integrate the strong benefits of lean associated with the waste minimisation and the quality product development efficiencies through six sigma which in current scenario images as one of the most desired requirements from the perspective of managers associated with SLSS adoption in the manufacturing organisations (Antony and Sony 2021). It is further noticed that the significant increase in the environmental concerns the customers as well as the market competition it has become essential for the managers involved in the production system to ensure that the sustainability aspects, regulatory compliances, and alignment of product development activities are aligned with the sustainable development goals (Dangelico and Pontrandolfo, 2015). In this aspect SLSS emergence as the prime choice of the managers and practitioners in the manufacturing organisations (Bag et al. 2021).

2.1 Enablers of Sustainable Lean Six Sigma

The effective adoption of SLSS can be achieved only when the associated enablers involved as identified and penetrated effectively in the entire manufacturing system. The neablers associated with SLSS adoption as basically the trigger factors that not only assists in its penetration but also helps the system to integrate the process effectively and

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enhance the adoption possibility. Based on existing literature, the present study works on the integrated lean, six sigma and sustainability concept altogether, in order to achieve the desired organisational performance within the system. A set of unique 25 SLSS enablers have been identified for this study and grouped into five major categories: Strategic and Policy-Oriented, Managerial and Human Capital, Process Optimisation, Technology and Digital Integration, and Organisational and Supply Chain Capability. Table 1 represents the list of 25 critical enablers that influences the SLSS adoption is reported.

Table 1: SLSS enablers identified through literature review

S. No.	SLSS Enabler	Description
1	**Financial Resources Availability**	Adequate financial investment facilitates training, technology adoption, and project execution. It reduces implementation delays and ensures smooth integration of SLSS practices.
2	**Cross-Functional Collaboration**	Coordination between departments enables knowledge sharing and reduces process bottlenecks. It ensures holistic implementation across the value chain.
3	**Employee Involvement**	Active participation of employees fosters ownership in SLSS projects and encourages idea generation. It strengthens collaborative culture and accelerates process improvements.
4	**Resource Efficiency Improvement**	Optimizing resource use enhances productivity and reduces environmental burden. It ensures sustainable material, energy, and water utilization.
5	**Training and Skill Development**	Continuous training equips employees with necessary lean, six sigma, and sustainability competencies. It enhances problem-solving abilities and promotes a skilled workforce.
6	**Supplier Integration and Collaboration**	Integrating suppliers ensures material quality, reduced waste, and timely delivery. Collaborative relations help extend SLSS practices across the supply chain.
7	**Performance Measurement System**	Robust KPIs help track process efficiency, sustainability outcomes, and defect reduction. Measurement enhances transparency and guides improvements.
8	**Waste Minimisation Practices**	Systematic waste reduction techniques reduce non-value-added activities and costs. It promotes eco-efficiency and supports lean operations.
9	**Use of Green Technologies**	Adoption of energy-efficient, low-waste technologies supports environmental sustainability. It reduces ecological impact and improves operational efficiency.
10	**Top Management Commitment**	Strong leadership support ensures strategic alignment, resource allocation, and long-term continuity of SLSS initiatives. It drives organizational culture toward excellence and sustainability.
11	**Strong Organisational Culture**	A culture that supports improvement, innovation, and sustainability enhances SLSS adoption. It strengthens internal motivation and continuous improvement orientation.
12	**Customer Focus and Engagement**	Understanding customer expectations encourages sustainable and defect-free product delivery. Customer participation guides prioritization of improvement areas.

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13	**Regulatory and Policy Support**	Supportive policies and environmental regulations push firms toward sustainable practices. Compliance requirements accelerate SLSS adoption.
14	**Knowledge Management and Sharing**	Effective knowledge capture and dissemination enable replication of best practices. It promotes informed decision making and faster SLSS implementation.
15	**Data Availability and Quality**	Reliable, accurate data improves decision-making and supports six sigma statistical analysis. High-quality data strengthens sustainability assessments.
16	**Robust Project Selection and Prioritization**	Selecting high-impact, sustainability-linked projects ensures maximum benefit from SLSS. Prioritization aligns improvement efforts with strategic goals.
17	**Risk Management Practices**	Identifying and mitigating process and sustainability risks enhances stability. It ensures consistent performance and reduces uncertainties.
18	**Sustainable Supply Chain Practices**	Integrating sustainability into sourcing, logistics, and distribution enhances overall environmental performance. It supports circular thinking in operations.
19	**Organisational Learning Capability**	Learning-oriented organizations rapidly adapt to SLSS techniques and innovations. It enhances long-term improvement and sustainable performance.
20	**Continuous Improvement Culture (Kaizen)**	Kaizen-based mindset encourages frequent, incremental improvements. It strengthens sustainability by reducing waste and optimizing processes regularly.
21	**Stakeholder Engagement**	Engaging all internal and external stakeholders strengthens commitment to sustainability. Their involvement improves transparency and long-term success.
22	**Technological Infrastructure Readiness**	Modern digital tools enable data-driven analysis and process monitoring. Adequate technological capabilities strengthen SLSS execution.
23	**Employee Health and Safety Practices**	Safe working environments support workforce wellbeing and productivity. It aligns operational improvements with sustainable development goals.
24	**Change Management Effectiveness**	A structured approach to handle resistance enables smooth implementation. It ensures acceptance and long-term institutionalization of SLSS.
25	**Effective Communication Mechanisms**	Clear communication ensures alignment of objectives, project clarity, and stakeholder engagement. It minimizes resistance and enhances smooth implementation.

At the strategic level, leadership commitment, regulatory compliance, sustainability-oriented policy frameworks, long-term environmental vision, and customer-driven sustainability expectations form the backbone of SLSS adoption (Antony, 2014). The higher management authorities should get involved in the strategic decisions within the system so that the organisational goals are properly linked to the sustainability objectives associated within the system. The sustainability-oriented aspects help in building the healthy culture towards green design, green procurement, environmental awareness within the inbound and outbound customers of the system associated. They predefined strategies keeps the system aligned and the activities accurately monitored in order to

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improve the success possibility of SLSS adoption among the manufacturing organisations.

Human capital is a key towards the SLSS adoption in manufacturing organisations because without cooperation of employees, their skill training, and awareness towards sustainability aspects of SLSS, it is extremely difficult to adopt SLSS effectively (Govindan et al., 2015).

It is important to organise focused training programmes that emphasises on sustainability, Lean, and Six Sigma concepts and provide a deeper understanding to the associated employees involved in SLSS adoption process to develop the desired technical and behavioural competencies which can certainly help them enhance the adoption (Vinod and Joy, 2012).

Cross-functional collaboration helps in penetrating the process information on a real-time basis and also help them taking proactive actions (Garcia et al., 2022). Strong leadership and management involvement motivates the employees and also helps them to enhance the employee performance. Moreover, a culture of continuous improvement encourages consistent quality improvement and waste reduction system that helps in improving the productivity (Anvari et al. 2021).

The process optimisation is another important factor which highly infuences the adoption of any quality methodology within the system; as in the case of present study it can also be included that lean and six sigma collectively helps in aligning the process effectively to improve the desired production (Cherrafi et al., 2017).

The waste reduction, removal of non-value-added activities, quality control, monitoring the activities and taking corrective action through VSM approach assist the managers associated in the SLSS adoption process to manage the system effectively and promote sustainability (Alhuraish et al. 2021).

The technology-oriented initiatives in manufacturing organisations helps in aligning the automation within the entire system. It further promotes the industry 4.0 culture among the process structure so that cyber physical activities can be aligned accordingly and help the pracittioners to penetrate real-time activity monitoring system that can improve the overall activity mapping (Agrawal et al. 2022).

2.2 Summary of Literature Gap

The review of existing literature highlights three major gaps:

- There are very limited studies available in the existing literature that can focus specifically identification of SLSS enablers and prioritising them.
- The identification and usage of analytical approaches to compute the intensities of SLSS is rarely reported in the existing literature.
- A very few studies have utilised fuzzy AHP approach for computation of SLSS intensities specifically in the manufacturing organisations of developing economies.

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This study addresses these gaps by identifying 25 key enablers of SLSS, applying a fuzzy AHP-based analytical model, and offering insights that support organisations in strengthening sustainability-oriented improvement initiatives.

3. RESEARCH METHODOLOGY

The present research work utilises a systematic approach to extract the most suitable SLSS enablers focusing the manufacturing organisations of developing economies specifically because of its low adoption rate. It further helps the practitioners working in the similar domain to identify and compute their intensity of influence and also report how they affect the overall SLSS adoption process. The computation of SLSS enabler weight is obtained capturing the inputs from the industry experts with the help of fuzzy analytical hierarchy process approach. The fuzzy inclusion will assist in removal of biasness among the captured judgements.

3.1 Identification and Validation of SLSS Enablers

A set of 25 unique SLSS enablers suited for manufacturing environment were finalized through a three-step process:

Step 1: Literature Review

An extensive review of research articles, industrial reports, and case studies from Lean, Six Sigma, sustainable operations, green supply chain management, and organisational capability literature was conducted. This helped identify a wide range of potential enablers relevant to SLSS adoption.

Step 2: Consolidation and Screening

Initial screening eliminated overlapping, redundant, or contextually irrelevant items. The remaining enablers were evaluated for clarity, relevance, and applicability in the context of emerging-economy manufacturing industries.

Step 3: Expert Validation

A panel of 12 experts—comprising Lean Six Sigma consultants, sustainability officers, senior academicians, and manufacturing managers—validated the final list of 25 enablers. Experts reviewed definitions, ensured contextual relevance, and confirmed the completeness of the list.

Accordingly, the final set of 25 enablers was categorized into strategic, managerial, technological, process-oriented, and sustainability-driven elements. These enablers formed the foundation for subsequent Fuzzy AHP analysis.

3.2 Overview of the Fuzzy AHP Methodology

The Fuzzy Analytical Hierarchy Process (Fuzzy AHP) is an extension of the classical AHP method that incorporates fuzzy set theory to address vagueness and imprecision in human decision-making (Saaty, 1980).

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It is widely used in sustainability, supply chain, and multi-criteria decision-making research due to its ability to handle inconsistent and linguistic judgments. Hence, the usage of FAHP in the current context can be understood through below-mentioned reasons. (Abdel-Basset et al. 2021)

- Experts often find it difficult to express preferences numerically.
- Subjective evaluations are inherently uncertain, especially for organizational and behavioural enablers.
- Linguistic judgements provide more comfort and accuracy.
- Fuzzy logic allows conversion of linguistic terms into ranges instead of fixed values.
- It provides more stable and realistic weights compared to crisp AHP.

3.3 Linguistic Judgements and Fuzzy Representation

In this study, experts rated the relative importance of enablers using linguistic terms. Each linguistic term represents a triangular fuzzy number with a lower, middle, and upper value. For example- Equal importance, Moderate importance, Strong importance, very strong importance, Extreme importance. Instead of using exact numerical ratios, Fuzzy AHP uses fuzzy ranges to represent expert preferences (Zadeh 1965). This ensures greater flexibility and minimizes bias arising from forced numeric choices.

3.4 Pairwise Comparison Matrix Development

For 25 enablers, experts were asked to compare every enabler with every other enabler in pairs. These comparisons reflect how much more (or less) important one enabler is relative to another in enabling SLSS adoption. The pairwise matrices obtained from each expert were aggregated into a single fuzzy comparison matrix using geometric averaging. Aggregation at the fuzzy level ensures that extreme judgments do not distort the final results.

3.5 Fuzzy Priority Weight Computation

The next step involves computing fuzzy synthetic extents and deriving fuzzy weights. Conceptually, this process consists of:

1. Evaluating the importance of each enabler

The fuzzy comparison values reflect the level of importance based on expert consensus.

2. Comparing magnitudes

Fuzzy values for all enablers are compared to determine which contribute more significantly to sustainable Lean Six Sigma adoption.

3. Defuzzification

The fuzzy weights are converted into crisp values using centroid or similar methods. This step transforms fuzzy priorities into interpretable numeric weights.

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4. Normalisation

The weights are normalised so that they sum to 1. These normalized weights represent the final priority ranking of the 25 enablers. This conceptual sequence allows researchers to systematically determine which enablers hold the highest significance in supporting SLSS implementation.

4. RESULTS AND DISCUSSION

The fuzzy AHP approach has been utilised in this study to compute the intensity of SLSS enablers included in this study where a complete set of 25 enablers is being analysed. The results obtained are specifically achieved through the inupts of the expert panel included solving this multi-crtieria decision-making problem. The results obtained through the application of decision-making approach clearly reveals that the present structure of SLSS enablers is categorised among the high ranked, moderate ranked and low ranked enablers. It is advisable in this context to the managers and practitioners that the obtained results should be studied effectively and accordingly the strategies should be planned to implement SLSS effectively. The opinions obtained through the expert team were converted into defuzzified sets and obtain the crisp values for more precise analysis of the final set of 25 unique SLSS enablers that strongly influences the SLSS adoption in manufacturing organisations. Table 2 represents the intensity of SLSS enablers analysed in this study.

Table 2: SLSS enabler weights computed through decision making study

S. No.	SLSS Enabler	Code	Weight	Rank
1	Top Management Commitment	E1	0.081	1
2	Training and Skill Development	E3	0.074	2
3	Strong Organisational Culture	E6	0.066	3
4	Financial Resources Availability	E2	0.061	4
5	Continuous Improvement Culture (Kaizen)	E12	0.059	5
6	Employee Involvement	E4	0.057	6
7	Performance Measurement System	E14	0.056	7
8	Data Availability and Quality	E18	0.051	8
9	Robust Project Selection and Prioritization	E20	0.049	9
10	Cross-Functional Collaboration	E5	0.046	10
11	Knowledge Management and Sharing	E13	0.044	11
12	Change Management Effectiveness	E21	0.041	12
13	Technological Infrastructure Readiness	E17	0.038	13
14	Customer Focus and Engagement	E7	0.036	14
15	Sustainable Supply Chain Practices	E24	0.033	15
16	Supplier Integration and Collaboration	E8	0.030	16
17	Use of Green Technologies	E9	0.028	17
18	Resource Efficiency Improvement	E11	0.026	18
19	Waste Minimisation Practices	E10	0.023	19
20	Regulatory and Policy Support	E16	0.021	20
21	Organisational Learning Capability	E19	0.020	21
22	Risk Management Practices	E22	0.018	22
23	Employee Health and Safety Practices	E23	0.016	23
24	Stakeholder Engagement	E25	0.014	24
25	Effective Communication Mechanisms	E15	0.012	25

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The results show that high-ranking enablers mainly belong to strategic, managerial, and process-oriented dimensions, which reflects the organisational readiness required for SLSS adoption. The top management commitment emerges as high priority enabler which clearly indicates the involvement of the management and its importance in the SLSS adoption process. Many organisations keep themselves detached within the adoption process. However, keeping intact the SLSS adoption process, ensuring the involvement in the decision-making process, defining the dedicated budgets and financial allocations within the system ensures the smooth ongoing process of the implementation. Aligning the organisational goals with the new process improvement adoption process always required the commitment from the management and their involvement directly improves the success possibility of the SLSS adoption within the manufacturing organisations.

The smooth adoption of SLSS adoption directly corelates with the budget allocation towards the SLSS training, technological advancement, digitisation of activities and sustainability adoption. It is often captured in literature that lack of availability of financial resources are the primary reason behind the SLSS adoption failures. Naturally, the availability of the financial resources emerges as the key enabler influencing the SLSS adoption process. Similarly, the investment towards training and skill development of the employees is required on the priority basis to ensure the development of healthy and sustainable organisational culture.

The continuous improvement which is linked with the kaizen concept is also an important concern when it comes to SLSS adoption. If a strong organisational culture is built with an appropriate involvement of employees associated with the SLSS adoption process then it becomes much easier to adopt SLSS effectively. It is further noticed in the analysis that most mid-ranked enablers fall under operational, process, and technological factors. The enablers falling under this category depends on the strong execution high priority enablers as reported in the top of the table in this study. The performance of these mid-ranked enablers strong depends on the penetration of high ranked enablers as it strongly focuses on the adoption state. Several enablers which appear to be of common practice, but they emerge as crucial factors when observed from the SLSS adoption perspective for example effective performance measurement system, employee involvement, cross-functional collaboration, data availability and quality. Strong employee involvement directly enhances the chances of SLSS adoption as they are the key pillars in the adoption process. The effective performance measurement system helps in measuring the performance at each level and it further helps to compute the contribution of several factors in the success of SLSS adoption and improving the organisational performance with the desired financial gains within the system of the manufacturing environment. The availability of data and maintaining the quality also emerges as prime concern with priority weights in the MCDM analysis.

In the overall adoption of SLSS the mid ranked and low ranked enablers also play a vital role. It can be clearly observed that without the cross functional collaboration it is extremely difficult to adopt SLSS effectively. Similarly, the change management

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effectiveness and the technological infrastructure readiness helps in mapping the process activities effectively and ensure that the system is aligned properly. The customer focus and engagement are very important to ensure the financial flow effectively and achieve the desired profit from the system. Many organisations ignore this aspect during the implementation process which further leads to the SLSS adoption failures. On the other hand, ignorance towards the sustainabile supply chain management practices and supplier integration within the system is another reason behind the adoption failures. Hence, the strong focus the intensities of the SLSS enablers obtained in this study should be tracked carefully and the adoption strategies should be developed accordingly.

5. CONCLUSION AND FUTURE SCOPE

This study primarily focuses on identifying the crucial enablers that influence the SLSS adoption in the manufacturing organisations. This study utilises the fuzzy AHP approach to identify and analyse the SLSS enablers. A comprehensive set of 25 critical enablers is analysed through the fuzzy AHP approach and their intensities have been computer. The study findings clearly indicates that the majority of the enables are closely associated with the strategic and managerial oriented practices. Hence, it becomes essential for the practitioners and the managers associated in the SLSS adoption process to ensure that all the strategy and managerial specific decisions should be in line with the results obtained in this study and their strategies towards the SLSS adoption should be aligned in such a way that it helps in penetrating the high priority ranked in an enabler on priority basis which will further in hands the success possibility of SLSS adoption. The study for the reveals that human centric enablers also emerge priority concerns. Accordingly, the management should focus on the human centric activities which includes the employee training, employee empowerment and also include the rewards and recognition-based system that can boost the employee morale. Such initiatives will improve the organisational productivity and helps the managers to gain the financial goals defined by the management to develop a sustainable culture. Some important enablers that also improves the SLSS adoption includes process optimisation and sustainability-oriented parts into concern. Keeping these aspects in mind will boost the success possibility of the SLSS adoption and provide better research directions to the young researchers working in the SLSS domain.

5.1 Study Implications

The following implications of this study can be portrayed as per the outcomes of the analysis conducted within this study:

- Developing a comprehensive SLSS enabler framework that synthesises Lean, Six Sigma, and sustainability perspectives into a unified structure.
- Establishing sustainability enablers as mid-level drivers, providing new insights into the transitional nature of SLSS maturity in emerging economies.
- Highlighting Industry 4.0–aligned enablers (digital tools, data integration, analytics) as important but not yet dominant factors in SLSS adoption.

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- Scalability for manufacturing organisations can be understood as the study insights apply to both SMEs and large firms, especially those navigating budget constraints, environmental regulations, and global sustainability pressures.
- Skill development programs focused on Lean tools, Six Sigma methodologies, life-cycle thinking, green process design, and waste-to-value strategies.
- Structured project prioritisation based on sustainability impact assessment, cost–benefit analysis, and cross-functional relevance.

5.2 Study Limitations

Although the research provides meaningful insights, a few limitations must be acknowledged. Expert sample size and representation can be considered as a concern for limitations. The Fuzzy AHP method relies on the judgments of a finite group of experts. The generalisability of results may be influenced by expert backgrounds, industry sectors, and organisational contexts. Similarly, the focus on manufacturing industry has been another constraint in this study. The enablers identified and ranked are primarily relevant to manufacturing; other sectors (healthcare, logistics, services) may have additional or different SLSS enablers. The static nature of prioritisation is the other concern of this study. While Fuzzy AHP offers robust weighting, the influence of enablers may evolve as technologies advance, sustainability pressures strengthen, and regulations become stricter. It can be clearly observed that the study projects the context-specific outcomes. As the research was conducted in an emerging economy context, the results may differ in developed countries where sustainability drivers, technological penetration, and workforce maturity are significantly different.

5.3 Future Research Directions

The growing importance of sustainability, digital transformation, and customer-driven quality improvement provides a rich landscape for expanding SLSS research. Future scholars may consider the several research directions where they can extend their research related works. The focus on the multi-method approaches can be a matter of consideration. Future studies can integrate Fuzzy AHP with other MCDM methodologies—such as TOPSIS, DEMATEL, ISM, or Robust Best Worst Method—to develop deeper insights into relationships among SLSS enablers.

The structural relationships can be formed for a better hierarchical development. ISM or Total Interpretive Structural Modelling (TISM) can be used to classify enablers based on driving and dependence power, thereby transforming the prioritised list into a strategic roadmap. Furthermore, the fuzzy MICMAC analysis can identify enablers with high driving power that should be prioritised for strategic interventions. The researchers working in the same direction can also project the sector-wise SLSS models for automotive manufacturing, FMCG production, electronics industries, pharmaceuticals, public healthcare services etc. in order to have a better sector specific outcomes which can be directly used by the researchers and practitioners who are into the application domain in these organisations.

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