International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Barriers Identifications for LSS Using PLS-SEM Method for Electric Power Products Manufacturing Unit

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A B S T R A C T

The present study conducted an investigation into the obstacles linked to the adoption of Lean Six Sigma (LSS) in small and medium-sized enterprises (SMEs), utilizing PLS-SEM modeling as its main analytical method. The study examined both dependent and independent latent factors to identify the main restrictions that affect the perceived ability of SMEs to successfully deploy LSS. The inquiry was facilitated by the involvement of 150 industry professionals, who were surveyed to provide a full picture of the issues they faced. The model demonstrated a high level of predictive ability, as indicated by an R2 value of 0.80, which signifies its capacity to explain 80% of the variability in perceived implementation capacity. PTOC exhibited a substantial impact size on the dependent variable, but RIC and SAFP demonstrated moderate effects. However, several components such as CEC, MCV, and OCCR did not provide a meaningful contribution to explaining the variance, indicating potential topics for additional investigation. The study establishes a basis for businesses to proactively overcome these obstacles, creating a favorable atmosphere for the adoption of LSS.

Keywords: LSS, SMEs, PLS-SEM, barriers, Readiness development, Latent variables

1. Introduction

To be competitive in a crowded market, businesses have become more focused on ensuring high quality during the previous sixty years. Statistical Process Control (SPC), ISO quality standards, Quality Management Systems (QMSs), Quality Checks (QCs), benchmarking, Total Quality Management (TQM), and similar tools have greatly influenced manufacturing organizations in this situation. Architects of high caliber are now using the 'Keep it Simple' equation as a standard to assess the quality of their work, with the aim of enhancing the overall efficiency of their respective organizations. Various quality control methods and standard operating procedures are currently being applied in the current dynamic, unstable, and competitive industrial environment. It is widely recognized that nearly all manufacturing processes and their accompanying procedures will exhibit some level of variation. The many discrepancies in the measurements can be classified into two categories: those resulting from internal or regular factors, and those arising from exceptional circumstances. Prior instances are known as unavoidable factors, and they are responsible for intrinsic oscillations in the cycle. As a result of these circumstances, there has been a significant dissemination of traits, many of which seem to be rather typical and anticipated. Another form of diversity arises as a direct outcome of specific causes, which in turn are the result of ongoing causal effects or repercussions that are inherent to the present climate. To ensure the longevity and economic viability of any industry, it is imperative to enhance the way a product is presented in terms of its manufacturability, irrespective of the circumstances. Businesses in countries like India must prioritize their operations due to the ongoing population growth, despite the challenges of higher lending rates, expanding markets, and a diminishing GDP.

Industries frequently strive to expand their utilization bounds and enhance their output levels. Additionally, they regularly pursue intangible goals such as cultivating client loyalty and managing cultural affairs. Assets are employed to make these contributions and accomplish these aims. Six Sigma is a comprehensive approach that serves as both a philosophy and a strategy to enhance quality. It involves the analysis of data to get valuable insights into the main causes of quality problems and the subsequent implementation of controls to address these issues. Six Sigma is employed as both a philosophical approach and a methodology for improving quality (Aboelmaged 2010; Aggogeri, and Gentili 2008; Al-Mishari, and Suliman 2008). Six Sigma can effectively be used in any of the remaining distinct cycles that are overseen by various organizational units, but it is predominantly employed in manufacturing companies.

Every association possesses unique strengths and limits, as well as distinct qualities. Implementing Six Sigma as a research approach in such a setting might provide significant benefits to an organization's research endeavors. While implementing Six Sigma as a process improvement technique, a multitude of challenges will become evident. Charles Waxer (2004) argues that when considering the ease of implementing Six Sigma and the organizational demands, it is universally acknowledged that smaller organizations have some advantages and disadvantages. These little associations are more agile, flexible, and versatile than their larger counterparts. However, it is likely that they will lack access to certified professionals or have far less knowledge of Six Sigma compared to the extensive infrastructure and resources of large corporations. A small corporation has various alternatives for managing the expenses associated with preparation, such as hiring a professional to do the task or assembling a team of experts to provide specialized guidance for the specific activity. Many large organizations have established strategies to offer Six Sigma training to their employees as well as to their suppliers, retailers, customers, and the customers of their suppliers. India's economy has witnessed a growing importance of limited liability firms in recent years. These factors are crucial for the country's economic and technical advancement, as well as other domains. These smaller enterprises constitute a substantial portion of the country's total exports of goods and services and serve as a significant provider of job opportunities.

2. Literature Review

Barcia et al. (2022) performed a systematic evaluation to assess the influence of Lean Six Sigma (LSS) on sustainability by employing partial least squares structural equation modeling (PLS-SEM). Analysis of 50 papers demonstrated that LSS methods have a favorable impact on economic, environmental, and social factors, with respective impacts of 83%, 78%, and 70%. This study highlights the importance of using PLS-SEM to evaluate the consequences of LSS sustainability, which can serve as a basis for future research and administrative decision-making. In their study, Cherrafi et al. (2017) identified fifteen obstacles that hinder the implementation of Green Lean techniques. These barriers encompass factors such as insufficient knowledge and skills, financial limitations, and inadequate engagement from management. The utilization of Interpretive Structural Modeling (ISM) exposed the interconnection of various barriers, providing valuable insights for the successful mitigation of obstacles and the achievement of project objectives. Costa et al. (2019) provided a comprehensive account of a Six Sigma project conducted at an automotive firm. The study demonstrated the efficiency of DMAIC in lowering the number of defective units. By implementing process enhancements and utilizing quality tools, they successfully achieved a significant reduction in faults, leading to large cost savings. Gaikwad et al. (2020) investigated the obstacles to implementing Lean Six Sigma (LSS) in small and medium-sized enterprises (SMEs) and put up ways to overcome these hurdles. Their discoveries provide valuable direction for small and medium-sized enterprises (SMEs) seeking to improve performance by adopting Lean Six Sigma (LSS).

Hariyani et al. (2022) emphasized the factors that motivate the adoption of an Integrated Sustainable Green Lean Six Sigma Agile Manufacturing System (ISGLSAMS), highlighting its advantages in terms of several performance measures. They provide valuable insights that assist firms in developing strategic plans for sustainable manufacturing. Hariyani et al. (2023) conducted a thorough examination of the adoption of ISGLSAMS in the Indian manufacturing sector. They specifically analyzed how the factors driving its adoption affect operational, market, and sustainable performance. Their discoveries provide essential understanding for governments and enterprises aiming to utilize ISGLSAMS for a competitive edge. Kumar et al. (2022) identified and ranked obstacles to implementing Lean Six Sigma (LSS) in Indian industry, specifically in the context of Industry 4.0. Their research provides insights into methods for overcoming these obstacles and optimizing the advantages of LSS in sophisticated production environments. Kumar et al. (2013) and Kumaravadivel and Natarajan (2013) showcased the effectiveness of Six Sigma in enhancing casting operations, highlighting its ability to reduce defects and optimize the overall process. These studies emphasize the significance of using systematic approaches such as PLS-SEM, ISM, and DMAIC to improve organizational sustainability, quality, and efficiency through the use of LSS and Green Lean methodology.

The main goal of this article is to carefully identify and thoroughly pinpoint the main obstacles or hurdles encountered by Small and Medium-sized Enterprises (SMEs) in the transformer manufacturing industry while trying to implement Lean Six Sigma methodology. Although we recognize prior studies on obstacles in different industries, our attention is solely directed towards small and medium-sized enterprises (SMEs) in the transformer manufacturing industry. This meticulous attention ensures the recognition of distinct, sector-specific obstacles that could otherwise be disregarded in a more comprehensive inquiry.

3. Latent variables and Observed variables in PLS SEM

The expert opinion study distilled a list of crucial latent variables essential for understanding barriers to Lean Six Sigma (LSS) adoption in SMEs of the electrical power products manufacturing industry. Initially, a multitude of potential variables emerged, reflecting diverse dimensions of LSS adoption. Academic and industry experts played a vital role in refining this pool, consolidating over 30 variables into 10 pivotal ones. Notably, variables like "Employee's perception of LSS" merged into broader themes such as "Organizational Culture and Change Resistance." The dependent variable, "Perceived Capacity to Implement LSS," gauges SMEs' confidence and feasibility in integrating LSS amidst identified barriers. Independent latent variables encompass concerns like "Management Commitment and Vision," "Training and Expertise Availability," and "Operational Disruptions Concerns," addressing leadership, practical challenges, and operational apprehensions.

Table 1 Final Latent variables (Independent and Dependent) with Measured Items

S.No	**Latent Variables|**	**Short Term**	**Measured Items**
1	Management Commitment and Vision	MCV	Top management's perceived support for LSS. Clarity of organizational goals in relation to LSS. Perceived importance of LSS by the leadership.

S.No	Latent Variables|	Short Term	Measured Items
2	Training and Expertise Availability	TEA	Perceived access to quality LSS training. The belief in the organization's capability to develop LSS expertise. Perceived value of specialized LSS training
3	Operational Disruptions Concerns	ODC	Potential interruptions caused by LSS initiatives. Difficulty in retaining benefits of initial LSS improvements. Concerns over time and costs in LSS project executions.
4	Organizational Culture and Change Resistance	OCCR	Employee's perceived resistance towards LSS-induced changes. Alignment of current organizational culture with LSS principles. Importance of human factors in LSS initiatives.
5	Communication and External Collaboration|	CEC	Perceived effectiveness of internal communication for LSS projects. Valuation of external collaborations and partnerships in LSS. Expected alignment between suppliers and customers in LSS initiatives.
6	Metrics, Tools, and Process Selection	MTP	Confidence in selecting relevant process metrics. Comfort with LSS tool selection and application. Ability to prioritize and align LSS projects with business needs.
7	Awareness and Employee Engagement	AEE	Overall awareness of LSS benefits among employees. Expected employee engagement in potential LSS projects. Organizational openness to promote LSS principles.
8	Resource and Infrastructure Concerns	RIC	Perceived adequacy of resources for LSS projects. Availability of technological support for LSS. Confidence in infrastructure's capability to support LSS initiatives.
9	Strategic Alignment and Future Planning	SAFP	How well LSS aligns with the organization's future vision. Perceived ability to match LSS projects with customer demands. Clarity in how LSS can fit into the strategic roadmap.
10	Process Thinking and Ownership Concerns	PTOC	Organizational inclination towards process-oriented thinking. Perceived clarity in defining process ownership for LSS.
11	Perceived Capacity to Implement LSS	PCI	Our organization feels confident about implementing LSS in the future. Given the right resources, we see LSS as a viable method to improve our processes. We believe that overcoming the identified barriers would enable successful LSS adoption. LSS implementation seems feasible for our organization in the foreseeable future. Our organization is likely to consider LSS adoption once key barriers are addressed.

4. Demographic analysis

The PLS-SEM analysis was conducted on a sample of 150 participants, whose demographic composition yielded a diverse range of insights into the characteristics of the respondents. The demographics played a crucial role in providing contextual backgrounds, assuring a diverse representation, and enabling more detailed analysis of the survey outcomes. Knowledge of demographic characteristics aids in identifying potential trends, biases, or impacts that specific groups may display towards the obstacles to adopting Lean Six Sigma in small and medium-sized enterprises (SMEs). The analysis was enriched by the inclusion of diverse demographic data, such as gender distribution and years of experience in the transformer manufacturing industry. The demographic analysis of the 150 participants is presented in table 2.

Table 2 Participants demographic results

Demographic Factor	**Category**	**Number of Respondents**	**Percentage (%)**
Gender	Male	95	63%
	Female	55	37%
Age Group	Till 35	45	30%
	36-40	60	40%
	41-50	30	20%
	51 & above	15	10%
Years of Experience	1-5 Years	50	33.30%
	6-10 Years	55	36.70%
	11-15 Years	30	20%
	16 & above	15	10%
Educational Level	Diploma	20	13.30%
	Bachelor's	70	46.70%
	Master's	50	33.30%
	PhD	10	6.70%

5. Result and Discussion

The measurement model, commonly known as the outer model in the context of PLS-SEM, establishes the basis for evaluating the connections between observable indicators and their corresponding latent variables. Conducting a thorough assessment of the measurement model was crucial in order to guarantee that our indicators accurately reflect the obstacles to adopting Lean Six Sigma (LSS) in small and medium-sized enterprises (SMEs). The evaluation is based on two main criteria: reliability and validity. Reliability assesses the degree of consistency in measurement, ensuring that our indications for each underlying variable are coherent and aligned. In order to achieve this objective, the reliabilities of individual items were examined to ensure that each item's correlation with its underlying variable was sufficient. The composite reliability of each construct was assessed to confirm that the components were effectively blended to create a dependable scale.

Validity, however, ensures that the indicators accurately measure what they are designed to assess. Convergent validity was evaluated by analyzing the Average Variance Extracted (AVE) for each construct, to ensure that a substantial amount of the variability in the indicators was accounted for by the underlying variable. Discriminant validity was confirmed by the use of the Fornell-Larcker criterion and by examining the cross-loadings. It was crucial to ensure that a hidden variable had a stronger correlation with its own indicators than with the indicators of another concept. Evaluating the measurement model is an important step before assessing the structural model. A reliable and valid measuring model ensures that future findings on the relationship between barriers (latent factors) and their influence on the perceived ability to adopt LSS are based on accurate and trustworthy data. The path model utilized in the current investigation was depicted in figure 1 using SmartPLS software.

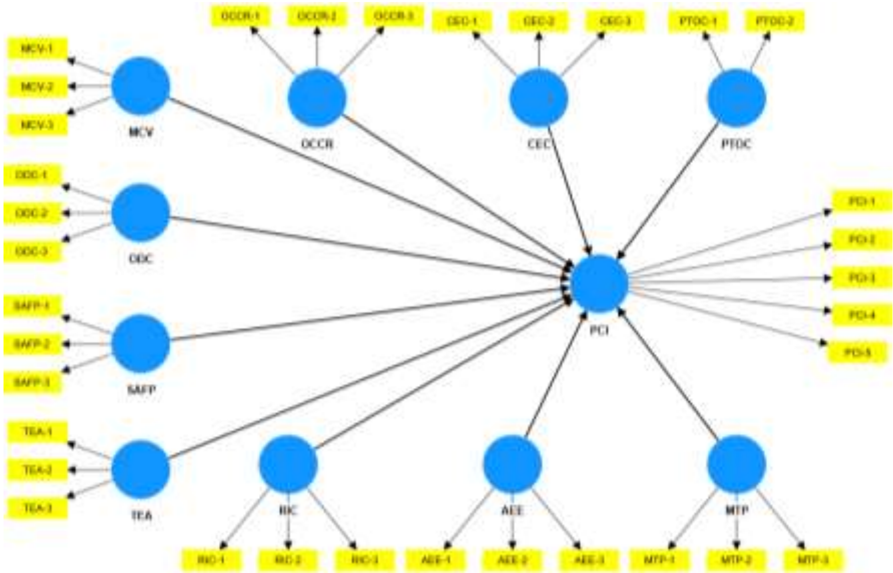

Figure 1 Path model developed for PLS-SEM modeling

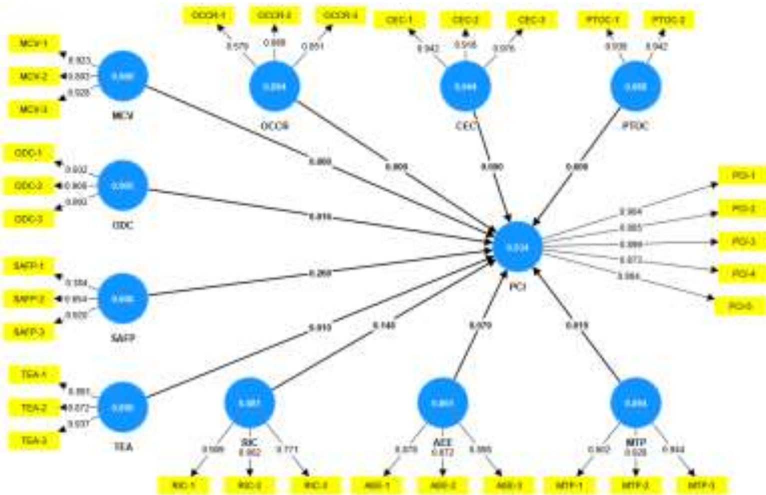

Figure 2 Measurement model analysis for factor loadings with Cronbach's Alpha and f^2 analysis

6. Conclusion

This study has yielded useful insights into the obstacles that hinder the implementation of Lean Six Sigma (LSS) in Small and Medium-sized Enterprises (SMEs) operating in the transformer manufacturing sector. Through a thorough process of identifying and assessing these obstacles, we have improved our comprehension of the difficulties that are impeding the adoption of LSS techniques in this particular setting. By employing Partial Least Squares Structural Equation Modeling (PLS-SEM), we were able to reveal the complex connections between the identified obstacles, providing insight into their combined influence on small and medium-sized enterprise (SME) operations. We have used expert opinion and consensus to create a concise list of important hidden factors that represent the main problems faced by small and medium-sized enterprises (SMEs) while adopting Lean Six Sigma (LSS). To empower SMEs in the transformer manufacturing business, it is crucial to address these hurdles and utilize the insights obtained from this study. This will enable them to overcome obstacles and improve their operational efficiency and effectiveness by successfully using LSS processes. This research establishes the foundation for future studies focused on creating customized approaches to support the deployment of Lean Six Sigma (LSS) and promote exceptional performance inside small and medium-sized enterprises (SMEs).

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