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An Integrated Lean Six Sigma Framework for Operational Excellence in Nigerian Manufacturing SMEs: Barriers, Critical Success Factors, and Performance Implications

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Abstract

Lean Six Sigma (LSS) combines waste reduction with process variation control, but adoption by manufacturing small and medium-sized enterprises (SMEs) may be constrained by limited resources, weak management support, skills shortages, and low familiarity with structured improvement methods. This study examines the relationships among barriers to LSS implementation, critical success factors (CSFs), LSS implementation practices, and operational performance among manufacturing SMEs in South-Eastern Nigeria. A quantitative cross-sectional questionnaire survey was conducted across Owerri, Aba, Onitsha, and Nnewi. Of 242 questionnaires distributed, 184 valid responses were retained for analysis. The instrument contained 24 construct items covering barriers, CSFs, LSS implementation practices, and operational performance. SmartPLS 4.0 was used to assess the measurement and structural models, with significance evaluated using 5,000 bootstrap resamples. The reported results indicate a negative relationship between barriers and LSS implementation ($\beta = -0.412$, $t = 6.124$, $p < .001$), a positive relationship between CSFs and LSS implementation ($\beta = 0.587$, $t = 9.452$, $p < .001$), and a positive relationship between LSS implementation and operational performance ($\beta = 0.680$, $t = 11.210$, $p < .001$). The model explains 51.2% of the variance in LSS implementation ($R^2 = 0.512$) and 46.2% of the variance in operational performance ($R^2 = 0.462$). The findings support a practical implementation pathway for resource-constrained SMEs that combines leadership awareness, low-cost Lean tools, simple data collection, a focused pilot project, and routine improvement reviews. Given the cross-sectional design, the estimated relationships are interpreted as associations rather than proof of causation. The measurement statistics and original SmartPLS outputs should be retained for verification and auditability.

Keywords: Lean Six Sigma, Manufacturing SMEs, Critical Success Factors, Implementation Barriers, Operational Performance

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1. Introduction

Manufacturing small and medium-sized enterprises (SMEs) contribute to employment, local supply chains, product availability, and industrial development. Their performance, however, can be affected by production delays, inconsistent quality, avoidable waste, equipment downtime, rework, and rising operating costs. These challenges are particularly difficult for firms with limited financial and technical resources, where improvement initiatives may compete with day-to-day operating needs.

Lean Six Sigma (LSS) integrates Lean principles, which seek to remove non-value-adding activities, with Six Sigma methods, which seek to reduce process variation and defects. It provides a structured approach to understanding process problems, selecting improvement projects, measuring performance, analysing causes, testing changes, and sustaining gains. DMAIC, meaning Define, Measure, Analyse, Improve, and Control, is one of the best-known LSS improvement cycles. Successful implementation nevertheless depends on more than the availability of tools. Leadership commitment, employee involvement, training, data availability, project selection, and a supportive improvement culture influence whether LSS becomes part of routine operations (Antony & Bañuelas, 2002; Laureani & Antony, 2012; Snee, 2010).

SMEs may face specific barriers to implementation, including limited training budgets, competing production priorities, inadequate measurement systems, weak internal expertise, employee resistance, and infrastructure constraints. Research on SMEs has highlighted the importance of adapting implementation approaches to the size and resources of the organization rather than transferring large-enterprise programmes without adjustment (Timans et al., 2012). Nigerian research has also considered the relevance of LSS to manufacturing SMEs and the factors that may affect implementation (Okpala, 2013; Odeyinka & Adegoke, 2023, preprint).

Despite growing interest in process improvement, further context-specific evidence is useful on how implementation barriers and critical success factors relate to LSS adoption and perceived operational performance among manufacturing SMEs in South-Eastern Nigeria. This study addresses that need by examining the relationships between barriers, CSFs, LSS implementation practices, and operational performance using questionnaire data and partial least squares structural equation modelling (PLS-SEM).

1.1 Aim and Objectives

The aim of the study is to examine an integrated framework linking barriers and critical success factors to Lean Six Sigma implementation and operational performance among manufacturing SMEs in South-Eastern Nigeria.

The specific objectives are to:

- assess the relationship between barriers to LSS implementation and the level of LSS implementation;
- examine the relationship between critical success factors and LSS implementation;
- evaluate the relationship between LSS implementation practices and operational performance;
- develop a practical, resource-sensitive roadmap for LSS implementation in manufacturing SMEs.

1.2 Research Hypotheses

H1: Barriers to LSS implementation are negatively associated with LSS implementation.

H2: Critical success factors are positively associated with LSS implementation.

H3: LSS implementation is positively associated with operational performance.

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2. Literature Review

2.1 Lean Six Sigma and Operational Improvement

Lean focuses on identifying value from the customer's perspective and reducing waste in process flow. Six Sigma complements this focus by using measurement and analysis to reduce variation and defects. LSS combines these perspectives to support improvements in quality, lead time, cost, productivity, and customer satisfaction. Snee (2010) describes LSS as an approach that can continue to improve when it is integrated into organizational routines rather than treated as a one-off initiative.

For SMEs, implementation should be proportionate to operational complexity and available resources. A small manufacturer may begin with workplace organization, visual controls, basic process mapping, standard work, and simple defect or downtime logs before introducing more advanced statistical methods. Timans et al. (2012) found that LSS implementation in manufacturing SMEs involves both success factors and impediments, emphasizing the importance of adapting methods to the realities of smaller organizations.

2.2 Barriers to LSS Implementation

Barriers are conditions that make it difficult for an organization to initiate or sustain LSS practices. The present study operationalizes barriers through six areas: insufficient funds for training, unreliable electricity supply, weak management support, employee resistance, shortage of skilled staff, and poor data culture. These barriers may limit the ability of a firm to train staff, collect reliable process information, allocate time to improvement, and maintain new standards. Reviews of Lean Six Sigma implementation failures have similarly emphasized leadership, organizational culture, training, communication, and resource-related challenges (Albliwi et al., 2014).

2.3 Critical Success Factors

Critical success factors are organizational conditions and practices that facilitate implementation. In this study, the CSF construct includes top management support, employee training, customer focus, readiness for change, resource availability, project selection, and continuous improvement. Leadership can make improvement work legitimate by allocating time and resources, while training helps staff understand the methods and contribute to problem-solving. Customer focus can guide project selection toward outcomes that matter, and continuous improvement routines can help sustain changes. These themes are consistent with the broader Six Sigma implementation literature (Antony & Bañuelas, 2002; Laureani & Antony, 2012).

2.4 LSS Practices and Operational Performance

The LSS implementation construct covers 5S, value-stream mapping, DMAIC, visual management, and standard work. These practices provide a practical toolkit for organizing workspaces, understanding process flow, investigating recurring problems, making performance visible, and reducing unnecessary variation in work methods. Operational performance is measured through perceived product quality, production or cycle time, operating costs, delivery performance, productivity, and customer satisfaction. These measures represent outcomes that SMEs can monitor using routine operational records.

2.5 Conceptual Model

The proposed model positions barriers and CSFs as predictors of LSS implementation, and LSS implementation as a predictor of operational performance. The model therefore contains three hypothesised paths:

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Barriers → LSS implementation; CSFs → LSS implementation; LSS implementation → Operational performance.

The framework assumes that barriers are negatively associated with implementation, while CSFs are positively associated with implementation and implementation is positively associated with operational performance. The model does not assume that all barriers or success factors have equal influence; the reported path coefficients summarize the relationships between the measured constructs.

3. Research Methodology

3.1 Research Design

The study adopted a quantitative, cross-sectional survey design. Questionnaire data were collected from manufacturing SMEs in Owerri, Aba, Onitsha, and Nnewi in South-Eastern Nigeria. The design enables analysis of the relationships among the study constructs at a defined point in time. Because the data are cross-sectional and based on respondent reports, the findings are interpreted as statistical associations rather than definitive evidence of causation.

3.2 Population, Sample Size, and Sampling Technique

The study population was estimated at 620 registered manufacturing SMEs across the four locations, based on the available business registration records used for the study. Yamane's finite-population formula was applied to estimate the target sample size (Yamane, 1967):

$$n = N / [1 + N(e^2)]$$

where n is the required sample size, N is the population size, and e is the acceptable margin of error. The study used a 5% margin of error, so e = 0.05.

Step 1: Substitute the known values

$$n = 620 / [1 + 620(0.05^2)]$$

Step 2: Calculate the squared margin of error

$$0.05^2 = 0.0025$$

$$n = 620 / [1 + 620(0.0025)]$$

$$n = 620 / [1 + 1.55] = 620 / 2.55 = 243.14$$

The calculated target sample was therefore approximately 243 firms/respondents. In the actual fieldwork, 242 questionnaires were distributed. Of these, 184 valid questionnaires were retained for analysis.

The valid response rate was calculated as follows:

$$\text{Valid response rate} = (\text{valid questionnaires retained} / \text{questionnaires distributed}) \times 100$$

$$= (184 / 242) \times 100 = 76.03\% \approx 76.0\%$$

A stratified random sampling technique was used. Aba, Onitsha, Nnewi, and Owerri constituted the four strata. Questionnaires were allocated proportionately to the estimated number of manufacturing SMEs in each location, and eligible firms were randomly selected from the available lists of registered manufacturing SMEs within each stratum.

Participating firms were required to be registered manufacturing SMEs employing between 10 and 199 people, to have operated continuously for at least three years, and to provide a respondent who was an

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owner, managing director, or senior operational manager knowledgeable about production and quality practices.

Location	Valid responses	Percentage
Aba	58	31.5%
Onitsha	49	26.6%
Nnewi	42	22.8%
Owerri	35	19.1%
Total	184	100.0%

3.3 Research Instrument and Measurement of Constructs

Data were collected using a structured questionnaire containing exactly 24 construct items. The items were grouped into four constructs: barriers to LSS implementation (6 items), critical success factors (7 items), LSS implementation practices (5 items), and operational performance (6 items). All items were rated on a five-point Likert scale, from 1 = Strongly Disagree to 5 = Strongly Agree.

Construct	Number of items	Measurement coverage
Barriers to LSS implementation	6	Training funding, power reliability, management support, employee resistance, skilled staff, data culture
Critical success factors	7	Management support, training, customer focus, change readiness, resources, project selection, continuous improvement
LSS implementation practices	5	5S, value-stream mapping, DMAIC, visual management, standard work
Operational performance	6	Product quality, cycle time, operating cost, delivery, productivity, customer satisfaction
Total	24	Four constructs

A pilot test involving 15 SME managers was conducted to assess item clarity, comprehensibility, and suitability. Feedback was used to improve the wording and presentation of the questionnaire. The pilot sample should be treated separately from the final sample unless the field records establish that pilot respondents were included in the main survey.

3.4 Data Collection and Ethical Considerations

Questionnaires were distributed to eligible respondents in the four locations. Participation was voluntary, and respondents were informed of the study purpose. Confidentiality and anonymity were maintained in the handling and reporting of responses. Of the 242 questionnaires distributed, 184 valid questionnaires were retained. The remaining 58 questionnaires were not retained in the final analytical sample.

3.5 Data Analysis and Model Evaluation

The data were analysed in SmartPLS 4.0 using partial least squares structural equation modelling (PLS-SEM). PLS-SEM was used to evaluate the measurement model and estimate the relationships specified in the structural model. Its use is consistent with methodological guidance that identifies PLS-SEM as useful for models with prediction-oriented objectives and multiple latent constructs (Hair & Alamer, 2022).

The measurement model was evaluated using indicator loadings, internal consistency reliability, convergent validity, and discriminant validity. Cronbach's alpha and composite reliability were used to

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assess internal consistency. Average variance extracted (AVE) was used to assess convergent validity. The Fornell-Larcker criterion was used to assess discriminant validity. The reported indicator loadings ranged from 0.714 to 0.881. Construct-level reliability and validity were evaluated against the study's stated criteria.

The structural model was evaluated using path coefficients, bootstrap t-statistics, p-values, and coefficients of determination (R^2). Significance was assessed using 5,000 bootstrap resamples. For reporting, a displayed p-value of .000 is expressed as $p < .001$, because a p-value is not literally zero.

4. Results

4.1 Respondent and Firm Characteristics

The final analytical sample consisted of 184 valid responses from manufacturing SMEs in four South-Eastern Nigerian industrial locations. The sample included firms from fabrication and metalwork, food and beverage, plastics, and other manufacturing sectors.

Characteristic	Category	Percentage
Manufacturing sector	Fabrication and metalwork	37.0%
Manufacturing sector	Food and beverage	28.3%
Manufacturing sector	Plastics	19.6%
Manufacturing sector	Other manufacturing	15.1%
Firm size	10-49 employees	55.4%
Firm size	50-199 employees	44.6%
Awareness of LSS	Respondents aware of LSS	33.2%

The sample profile indicates that more than half of the participating firms employed 10 to 49 people. Fabrication and metalwork represented the largest reported sector group. Only 33.2% of respondents were reported as aware of LSS, suggesting that basic awareness and training may be important starting points for an SME implementation programme.

4.2 Measurement Model

The reported indicator loadings ranged from 0.714 to 0.881. The manuscript records state that Cronbach's alpha and composite reliability exceeded 0.70 and that AVE exceeded 0.50 for the constructs.

The reported Fornell-Larcker matrix is shown in Table 4.

Construct	Barriers	CSFs	LSS implementation	Operational performance
Barriers	0.782			
CSFs	-0.324	0.804		
LSS implementation	-0.512	0.612	0.795	
Operational performance	-0.401	0.534	0.680	0.821

Note. Diagonal values are the reported square roots of AVE; off-diagonal values are construct correlations. Each diagonal value exceeds the absolute correlations between that construct and the other constructs.

4.3 Structural Model and Hypothesis Testing

Hypothesis	Structural relationship	Path coefficient (β)	t-statistic	p-value	Decision

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H1	Barriers → LSS implementation	-0.412	6.124	< .001	Supported
H2	CSFs → LSS implementation	0.587	9.452	< .001	Supported
H3	LSS implementation → Operational performance	0.680	11.210	< .001	Supported

The estimated path from barriers to LSS implementation was negative and statistically significant ($\beta = -0.412$, $t = 6.124$, $p < .001$), supporting H1. This result indicates that higher reported barriers were associated with lower reported LSS implementation.

The path from critical success factors to LSS implementation was positive and statistically significant ($\beta = 0.587$, $t = 9.452$, $p < .001$), supporting H2. This suggests that stronger leadership support, training, customer focus, readiness for change, resources, project selection, and continuous improvement were associated with greater LSS implementation.

The path from LSS implementation to operational performance was positive and statistically significant ($\beta = 0.680$, $t = 11.210$, $p < .001$), supporting H3. This indicates that stronger reported use of LSS practices was associated with better reported operational performance. The cross-sectional design does not establish that LSS implementation alone caused the observed performance differences.

4.4 Coefficient of Determination

Endogenous construct	R^2	Variance explained
LSS implementation	0.512	51.2%
Operational performance	0.462	46.2%

The R^2 value for LSS implementation was 0.512, meaning that the barriers and CSFs included in the model jointly accounted for 51.2% of the observed variance in LSS implementation. The R^2 value for operational performance was 0.462, meaning that LSS implementation accounted for 46.2% of the observed variance in operational performance within the specified model. These values describe explained variance in the sample; they should not be interpreted as percentages of performance improvement caused by the predictors.

5. Discussion

5.1 Barriers and LSS Implementation

The negative association between barriers and LSS implementation is consistent with the view that implementation requires time, resources, leadership attention, employee capability, and usable process data. Where training budgets are constrained, electricity supply is unreliable, skilled staff are scarce, or operational information is not systematically recorded, firms may find it difficult to establish a repeatable improvement process. This is particularly relevant to SMEs, where improvement tasks may be added to existing responsibilities rather than assigned to dedicated specialists. The result is broadly consistent with literature identifying organizational and resource-related impediments to Lean Six Sigma implementation (Albliwi et al., 2014; Timans et al., 2012).

5.2 Critical Success Factors and LSS Implementation

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The positive association between CSFs and LSS implementation highlights the role of managerial and organizational readiness. Top management support can protect time for improvement activities and communicate that process improvement is a business priority. Training equips employees with the basic concepts and tools needed to identify waste and investigate recurring defects. Customer focus and project selection help firms direct scarce resources toward problems with meaningful operational consequences. Continuous improvement routines can then help sustain changes. These interpretations align with established research on the conditions that support Six Sigma implementation (Antony & Bañuelas, 2002; Laureani & Antony, 2012).

5.3 LSS Implementation and Operational Performance

The positive association between LSS implementation and operational performance suggests that SMEs reporting greater use of 5S, value-stream mapping, DMAIC, visual management, and standard work also reported better quality, cycle time, cost, delivery, productivity, and customer satisfaction. The result is consistent with the central logic of LSS: make work visible, understand process flow, use data to identify causes, test corrective actions, and standardize effective practices. However, because the performance measures were collected through the same questionnaire at one point in time, the result should be interpreted as an association based on reported perceptions. Future longitudinal work using objective production records would help test whether LSS adoption precedes measurable changes in performance.

5.4 Implications for Manufacturing SMEs in Nigeria

The findings support a staged approach rather than an expensive, enterprise-wide implementation programme. Firms can begin with basic awareness, a small number of practical tools, simple paper or spreadsheet-based measures, and one well-defined pilot project. The aim should be to establish a repeatable improvement routine before investing in more advanced software or specialist training. Such an approach is consistent with the need to adapt LSS implementation to the context and resources of smaller firms (Timans et al., 2012).

6. Proposed Integrated LSS Implementation Roadmap

Based on the study model and the reported barriers, CSFs, and implementation practices, the following five-phase roadmap is proposed for resource-constrained manufacturing SMEs. It is a practical recommendation derived from the study framework, not an intervention whose effectiveness was directly tested in this cross-sectional survey.

Phase	Main actions	Practical outputs	Suggested timing
1. Awareness and leadership	Conduct a short, practical two-day introductory Yellow Belt-style workshop for owners and supervisors; identify one sponsor and communicate the purpose of improvement.	Named sponsor, trained core team, initial problem list.	Weeks 1-2
2. Low-cost Lean tools	Apply 5S and a simple current-state value-stream map to one production area.	Workplace checklist, process map, visible waste and delay points.	Weeks 3-4
3. Data-lite DMAIC	Use paper logs or a basic spreadsheet to record defects, rework,	Baseline measures and a clearly stated problem.	Weeks 5-6

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	downtime, cycle time, and delivery delays.		
4. Focused pilot project	Select one product or process line and run a three-month improvement project using DMAIC.	Documented actions, before-and-after measures, lessons learned.	Months 2-4
5. Sustain and review	Use visual boards, standard work, assigned owners, and monthly improvement meetings.	Control checklist, monthly review, updated standards.	Ongoing

The roadmap is designed to reduce the entry cost of implementation while addressing the factors represented in the study model. Leadership and awareness address the need for management support; practical training develops staff capability; simple logs address data limitations; a focused pilot reduces the risk of spreading resources too thinly; and routine reviews support sustained improvement.

7. Conclusion

This study examined the relationships among barriers to Lean Six Sigma implementation, critical success factors, LSS implementation practices, and operational performance among manufacturing SMEs in South-Eastern Nigeria. Using 184 valid questionnaire responses and PLS-SEM, the reported results showed a significant negative association between barriers and implementation, a significant positive association between CSFs and implementation, and a significant positive association between implementation and operational performance. The model explained 51.2% of the variance in LSS implementation and 46.2% of the variance in operational performance.

The results indicate that LSS implementation is associated with both organizational readiness and perceived operational outcomes. A staged, low-cost approach is recommended for SMEs that may lack dedicated improvement teams or advanced analytics resources. Since the study is cross-sectional and questionnaire-based, its findings should be understood as evidence of relationships among reported constructs rather than proof of causal effects.

8. Recommendations

1. Manufacturing SME owners and managers should provide visible leadership support and allocate time for structured improvement activities.
2. SMEs should begin with practical, low-cost tools such as 5S, visual management, standard work, and value-stream mapping before adopting more complex methods.
3. Firms should provide basic LSS training for owners, supervisors, and frontline workers, with emphasis on applying tools to actual production problems.
4. Each participating firm should select one pilot project linked to a measurable problem such as defects, rework, downtime, cycle time, or late delivery.
5. Firms should maintain simple records of quality, time, cost, and delivery performance using paper logs or spreadsheets where digital systems are unavailable.
6. Managers should review improvement results monthly and standardize changes that are supported by evidence.
7. Industry associations and public SME support agencies should consider practical, affordable LSS awareness and training programmes tailored to small manufacturers.
8. Future research should combine survey measures with objective operational data and longitudinal pre- and post-implementation observations.

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9. Contribution to Knowledge

The study contributes a context-specific integrated model linking implementation barriers and critical success factors with LSS implementation and perceived operational performance among manufacturing SMEs in South-Eastern Nigeria. It also translates the model into a five-phase roadmap intended to make implementation more accessible to firms with limited resources. The contribution is practical and empirical, while the cross-sectional design means that causal and longitudinal claims remain outside the scope of the evidence.

10. Limitations and Future Research

The study has several limitations. First, the cross-sectional design does not establish temporal order or causality. Second, the measures were collected through a structured questionnaire and may be affected by respondent perceptions or common-method bias. Third, the study covered four industrial locations in South-Eastern Nigeria, so the findings should not automatically be generalized to all Nigerian manufacturing SMEs. Future studies should use repeated measurements, objective production and quality records, broader geographical coverage, and follow-up studies of firms implementing the proposed roadmap.

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Appendix A. Construct Item Coverage

The following list summarizes the construct coverage used in the questionnaire. It describes the 24-item structure and is not a substitute for the exact item wording in the original instrument.

Construct	Item count	Coverage
Barriers	6	Training finance; power reliability; management support; resistance to change; skilled workforce; data culture.
Critical success factors	7	Management commitment; training; customer focus; readiness for change; resources; project selection; continuous improvement.
LSS implementation	5	5S; value-stream mapping; DMAIC; visual management; standard work.
Operational performance	6	Quality; production/cycle time; cost; delivery; productivity; customer satisfaction.

Appendix B. Equation and Reporting Guide

Sample-size equation:

$$n = N / [1 + N(e^2)]$$

Substitution:

$$n = 620 / [1 + 620(0.05^2)] = 620 / 2.55 = 243.14 \approx 243$$

Valid response rate:

$$(184 / 242) \times 100 = 76.03\% \approx 76.0\%$$

Interpretation of R^2: $R^2 = 0.512$ means 51.2% of the variance in LSS implementation is explained by the predictors in the specified model. $R^2 = 0.462$ means 46.2% of the variance in operational performance is explained by its predictor in the specified model. Neither value should be described as a percentage improvement in actual performance.

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