# SIX SIGMA AND PERFORMANCE OF SMALL SCALE MANUFACTURING FIRMS IN ABUJA

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## ABSTRACT
This study examined the effect of application of Six Sigma principles on performance of small-scale manufacturing firms in Abuja. Using a cross-sectional survey research design, data were collected from 205 respondents in selected small scale manufacturing firms through structured questionnaire administered to 370 participants using Goggle form. The measures of Six sigma are the dimensions of six sigma namely: process definition, process measurement, process diagnostics, process improvement, and process control while performance was measured by customer patronage indicators. Data were analyzed using regression analysis via SPSS Version 26. The findings revealed that application of the principles of: process definition, process measurement, process diagnostic, process improvement and process control have positive and significant effects on performance. On combining the five dimensions of six sigma, the result showed that all the five dimensions jointly predict performance with application of Six sigma principles having a positive and significant effect on performance with application of six sigma principles explaining 35% (*Adj.* $R^2$= .350) variation in performance. Individual contribution to performance in the combined model showed that process measurement, process improvement and process control have positive and significant effects on performance whereas process definition shows a statistically significant but negative effect on performance while process diagnostics was not statistically significant, indicating it does not contribute meaningfully to explaining performance outcomes in the combined process. Based on the findings, it is recommended that small scale manufacturing firm operating in Abuja should implement the five tools of six sigma most especially process measurement, process improvement and process control tools to enhance performance of their manufacturing activities.

**Keywords: Six sigma, firm performance, small-scale firm.**

## 1. INTRODUCTION

Six sigma is derived from the statistical concept "sigma". In Six sigma management concept, six times the theoretical standard deviation is allowed as maximum defects which translate to less than 3.4 defects per million opportunities (Mejjaouli & Algublan, 2020). It is a management concept developed by Motorola Company in the US in the 80s to meet increasing competition from Japan (Chakote et al., 2025). Today, competition is global and companies most especially the micro, small and medium enterprises must rise up to improve upon their processes to gain competitive advantage with the objective to meet the increasing competition (Gupta et al., 2023). Firms are looking inwards to develop and implement new management systems or adopt/adapt existing management systems that could enhance firm's structure, processes, market conditions, customers' needs, changes in technology to gain competitive advantage (Farida & Setiawan, 2022). Daniyan et al (2022) observes that improvement of process performance and product quality is a priority for any company to achieve organization's objectives of sustainability, profitability, market share, and competitiveness in this age of globalization and rising market competition. Poor products' quality results from manufacturing mistakes with negative effect on manufacturing costs and time (Ridwan et al., 2023). To address these, a more sustainable alternative is sought to achieve process optimization that will bring about efficiency in improvements programs, precision in manufacturing, absolute product design and production time or cycle enhancement (Setiawan, 2025).

Six sigma tools being a customer-oriented tool come handy to achieve the above purpose. It involves making manufacturing process more efficient, effective, competitive and delivering products with negligible or no defects with high reproducibility, eliminate waste to promote quality, productivity and customer satisfaction (Sakib et al., 2025). It consists of sets of five management tools namely: process definition, process diagnostic, process measurement, process improvement and process control which when implemented could bring about better organizational performance (Patel and Chudgar, 2020). Six sigma tools provide opportunities to compare firms in their efforts to achieve organizational objective in the face of competition. As a quality management philosophy, Six Sigma has been established as an important strategy for achieving competitive advantage with successful application in many organizations leading to sustainable performance improvements in products and services (Fahimi &Amirabadi, 2024). Ravindra et al (2023) reported that six sigma in the last few decades has been a top agenda in global corporate organizations as management tools for cost optimization and productivity improvement to enhance business benefit and gain competitive advantage through a continuous process of reducing defects in the organization. The goal of Six Sigma is to eliminate or reduce production errors or failures with a view to: increase customer satisfaction, lower production cost, achieve financial success and develop new products while continuously improving procedures (Ghelani, 2024).

It cannot be said that all is well with the manufacturing sector in Nigeria. The overall contribution of the sector to the GDP declined to 8.46% (second quarter of 2024) from 8.62% in second quarter 2023 (National Bureau of Statistics, 2024). The elected President of Nigeria Employers' Consultative Association (NECA) in his acceptance speech said "there are a lot of issues that are bothering manufacturers in this country". He went on to say that Nigeria's manufacturing sector is under siege. He mentioned some of the issues affecting the sector as: high energy costs, foreign exchange scarcity, rising inflation, insecurity, high interest rates, high logistics costs, predatory regulatory environment, and high cost of doing business (Young, 2024). Also, the President of

Manufacturers' Association of Nigeria (MAN), during the 52nd (2024) Annual General Meeting of the association opined that manufacturing is the major driver of the economy through creation of jobs and fostering innovation. He further said despite this, manufacturing sector in Nigeria has not realized its full potential due to multitudes of operational, structural and policies induced challenges making it to contribute low to the national GDP (8%). He further said that these challenges have effect on product quality making the products less competitive when compared with imported products in the local market (Moses, 2024).

The Chairman, Federal Inland Revenue Service (FIRS) during the 52nd AGM of Manufacturers' Association of Nigeria revealed that FIRS might not be able to collect taxes from manufacturers in Nigeria in the next ten years because "all manufacturing entity in Nigeria declared a total of N1.7 trillion losses (Onwuamaeze, 2024). The Chief Executive Officer of the Center for Promotion of Private Enterprise corroborated the fact that the manufacturing sector is experiencing hardship in an interview he granted to BusinessDay newspaper. He said that the manufacturing sector is one of the most vulnerable sectors amidst the ongoing economic reforms. He mentioned further that the reform is driving cost of production high thereby reducing business performance of the manufacturing sector, promoting export of primary products because secondary products manufactured in Nigeria are not competitive for export (Okojie, 2024). Empirical evidences in literature have shown that Six Sigma approach offers solutions to production issues like high cost of production, low quality products, less competitive products for export and low financial performance (Murmura & Bravi, 2021).

Abuja is one of the regions in Nigeria where manufacturing activities are currently on the increase due to the strategic importance of Abuja as the Federal Capital Territory of Nigeria. Currently, there is influx of manufacturing activities into Abuja due to the enhanced status and attention given to the region by the current democratic government which believes that every region of Nigeria must develop and become economic regions or zone rather than being just a political region or zone. In the first quarter of 2024, Abuja (FCT) received $593.58 million in direct foreign investment (NBS, 2024) representing 17.58% of total capital importation making Abuja the 2nd after Lagos in terms of DFI attraction. This has a lot of implications for manufacturing activities considering the fact that some of these DFIs are manufacturing based. However, with the current economic reforms many manufacturing concerns are not having things easy in Abuja and its environs as well as in Nigeria as a whole. Many of such companies have resulted to cutting corners in their production processes with effect on product quality and customer satisfaction (Moses, 2024).

In Nigeria, six sigma study is not popular leading to dearth of literature in this area of research endeavour (U-Dominic et al., 2025). Also, most studies on six sigma methodology found in literature are based on manufacturing firms operating at the South Eastern part of Nigeria with concentration on the overall effect of six sigma on performance and emphasis on financial performance (Akpan, et al., 2023; Nnabuife & Itua, 2021; Ogunwolu et al., 2021; Daniel, 2019; Okafor et al., 2018). Not many studies have been reported on examining the actual effect of each of the dimensions of six sigma on performance with focus on customer patronage as performance indicator. The aim of this study therefore, is to examine the effect of application of individual dimensions of six sigma on performance of small scale manufacturing firms in Abuja with a view to recommending the implementation of some specific tools of six sigma in their operations to enhance performance as well as to survive the current economic hardship in Nigeria occasioned by the current multiple economic reforms.

## 2. LITERATURE REVIEW

Conceptual Review

Six-sigma is an initiative to achieve zero defects and decrease variations in manufacturing/process industries with a view to improving customer satisfaction and patronage. It is a methodology that is focused on process improvement and defect reduction. It has evolved significantly since its inception at Motorola in the 1980s (Chakote et al., 2025). Recent literature provides diverse perspectives on its definition. Mejjaouli & Algublan (2020) emphasized that six sigma aims to minimize defects to 3.4 per million opportunities towards enhancing process quality, product quality, customer satisfaction and overall organizational performance.

Huang et al. (2023) describe Six Sigma as an integrative framework that combines statistical tools with management practices to drive operational excellence and sustainability. These definitions underscore Six Sigma's adaptability, with a consistent focus on quality, customer-centricity, and statistical rigor, reflecting its relevance in modern business contexts.

The characteristics of Six Sigma distinguish it as a robust quality management approach. It employs the DMAIC (Define, Measure, Analyze, Improve, Control) framework to systematically address process inefficiencies, as highlighted by Gupta et al. (2018), who noted its effectiveness in reducing material wastage in tire manufacturing. Six Sigma has also been integrated with other methodologies like Lean to enhance efficiency, particularly in sustainable manufacturing practices (Huang et al., 2023).

Cost savings are a major benefit of six sgma, with organizations reporting substantial financial gains through process optimization and fostering employee engagement by providing training and empowering staff to lead improvement initiatives, creating a culture of continuous improvement resulting in enhanced performance (Huang et al., 2023). The cost saving benefit of Six Sigma has made it a powerful tool for organizational competitiveness (Ilin et al., 2025).

**Process Definition**

Process definition, the first phase of the Six Sigma DMAIC methodology, involves identifying and documenting the process to be improved, aligning it with organizational goals and customer requirements. According to Sabtu (2024), this phase entails creating a clear problem statement, defining project scope, and establishing Critical to Quality (CTQ) metrics that reflect customer needs. Huang et al. (2023) emphasized that Process Definition requires stakeholder collaboration to map processes accurately. Often tools like SIPOC (Suppliers, Inputs, Process, Outputs, Customers) diagrams are used to visualize workflows. This step ensures that subsequent phases target the right issues, setting a foundation for measurable improvement.

The significance of Process Definition lies in its ability to align improvement efforts with strategic objectives and customer expectations. Gupta et al (2018) highlighted that a well-defined process reduces ambiguity, enabling teams to focus on high-impact areas, as seen in a tire manufacturing case where clear process mapping led to reduced material wastage. Effective Process Definition fosters cross-functional collaboration, ensuring that all relevant departments contribute to identifying inefficiencies, as noted in a review of Six Sigma applications in education (Sengupta et al., 2024). By establishing clear boundaries and goals, this phase enhances project success rates.

**Process Measurements**

Process Measurements, the second DMAIC phase, focus on collecting data to quantify process performance and identify variability. Ilin et al. (2025) define this phase as the systematic gathering of baseline data using statistical tools like control charts and histograms to measure defects and process capability. Sharma (2024) emphasizes the importance of selecting relevant metrics, such

as cycle time or defect rates, to ensure alignment with CTQ requirements. This phase establishes a factual basis for analysis, enabling data-driven decision-making critical to Six Sigma's methodology.

**Process Diagnostic**

Process diagnostics refers to the systematic evaluation of a process to identify performance gaps, anomalies, or inefficiencies, often serving as a preliminary or complementary step to formal process improvement methodologies like Six Sigma. Huang et al. (2023) define it as an assessment that uses diagnostic tools, such as key performance indicators (KPIs), flowcharts, or observational audits, to detect symptoms of process issues without necessarily identifying root causes.

**Process Improvement**

Process improvement, the fourth DMAIC phase, focuses on developing and implementing solutions to address root causes identified in the analysis phase. Sharma (2024) defines it as the application of strategies like process redesign, automation, or standardization to enhance performance and reduce defects. Huang et al. (2023) highlighted the use of brainstorming and pilot testing to ensure solutions are feasible and effective. This phase aims to achieve measurable gains in quality, efficiency, and customer satisfaction, aligning with Six Sigma's core objectives. Process Control

Process Control, the final DMAIC phase, ensures that improvements are sustained through monitoring and standardization. Ilin et al. (2025) defined it as the use of control plans, statistical process control (SPC) charts, and documentation to maintain process stability. Sirshar et al. (2024) emphasize the importance of training employees to adhere to new standards and using real-time data to detect deviations. This phase institutionalizes gains, preventing regression to prior performance levels. The significance of process control lies in its role in sustaining long-term quality improvements.

**Business Performance**

Business performance refers to the measurable outcomes of an organization's activities, reflecting its effectiveness in achieving strategic objectives. Antony et al. (2023) defined it as a multidimensional construct encompassing financial metrics (e.g., profit, revenue), operational efficiency (e.g., productivity, quality), and market outcomes (e.g., customer satisfaction, competitive position). Münch et al. (2024) emphasized its role in assessing organizational success through key performance indicators (KPIs) like return on investment and defect rates, often linked to process improvement methodologies like Six Sigma. Kaswan et al. (2024) describe business performance as a dynamic measure, incorporating sustainability and stakeholder value, as seen in food processing firms where performance improved through defect reduction. These definitions highlight business performance's comprehensive nature, integrating financial, operational, and strategic dimensions, critical for evaluating Six Sigma's impact.

The characteristics of business performance include its multidimensionality, measurability, and context-dependency. It is multidimensional, capturing financial (e.g., cost savings), operational (e.g., cycle time), and customer-focused (e.g., satisfaction) outcomes, as noted by Laureani and Antony (2023) in their retail studies. Context-dependency means performance metrics vary by industry, with manufacturing prioritizing efficiency and services emphasizing customer experience (Sodhi et al., 2024).

The advantages of focusing on business performance include strategic alignment, improved decision-making, and enhanced competitiveness. By tracking performance, organizations align processes with goals, as demonstrated in pharmaceutical firms where Six Sigma-driven improvements saved $150,000 annually (Antony et al., 2023). Measurable performance data

supports data-driven decisions, with retail inventory optimization cutting costs by 20% (Laureani& Antony, 2023). Strong performance enhances market position, as seen in food processing firms gaining brand reputation through quality improvements (Kaswan et al., 2024).
Since six sigma has focus on product quality improvement for customer satisfaction the performance measure adopted in this study are customer-focused precisely customer patronage (Sodhi et al., 2024; Antony et al., 2023; Laureani and Antony, 2023).

## 2.2 Theoretical Review

Total Quality Management (TQM) is a management philosophy with focus on achieving organizational excellence through continuous improvement and customer satisfaction. Originating in the mid-20th century, TQM was pioneered by W. Edwards Deming, Joseph Juran, and Kaoru Ishikawa, whose work transformed quality practices in post-war Japan and later globally (Martínez-Lorente et al., 1998). Deming emphasized statistical process control and employee empowerment, Juran introduced the quality trilogy (planning, control, improvement), while Ishikawa developed tools like the cause-and-effect diagram (Houston & Dockstader, 1997). TQM integrates these contributions into a holistic approach, prioritizing quality across all organizational functions. Some studies have affirmed TQM's enduring influence, with Antony et al. (2023) noting its adoption in pharmaceutical manufacturing to enhance product reliability, underscores its relevance in modern quality management.
TQM's relevance to Six Sigma and business performance lies in its complementary relationship with Six Sigma's data-driven methodology. TQM provides a cultural and philosophical foundation, while Six Sigma offers rigorous tools like DMAIC to operationalize quality improvements (McDaniel & Doherty, 1990). A 2023 study showed that combining TQM's employee focus with Six Sigma in pharmaceutical industry reduced defective batches by 12%, saving $150,000 annually (Antony et al., 2023). Similarly, TQM's continuous improvement ethos amplified Six Sigma's Process Improvement phase in retail, enhancing profitability (Laureani& Antony, 2023). Critics note that TQM's less structured approach may dilute Six Sigma's precision in complex processes (Sodhi et al., 2024). Nonetheless, TQM's integration with Six Sigma enhances business performance by fostering a quality culture that sustains long-term gains, making it a critical framework for Six Sigma research. This study is anchored on Total Quality Management Theory because the theory is all about product(s) improvement and customer satisfaction which are the goals is six sigma methodology as conceptualized in this study.

## 2.3 Empirical Review

Taneo et al. (2022) study demonstrated that by adopting tools such as DMAIC, 5S, and root cause analysis, SMEs can systematically identify inefficiencies and sources of waste throughout their production and storage processes. This structured approach not only facilitates the elimination of non-value-adding activities but also promotes a culture of continuous improvement. The study highlighted that the integration of Lean Sigma Six practices enables these enterprises to reduce defect rates, optimize the use of labor and materials, and shorten process cycle times. Consequently, SMEs become more agile and resilient, improving their ability to respond to market demands and maintain product quality. The result is enhanced operational performance, stronger competitiveness, and a more sustainable business model capable of supporting long-term growth, customer satisfaction and overall business performance.
Tita et al (2023) study used the DMAIC approach, five types of waste were identified in Mooncake production, with waiting time found to cause the greatest loss, contrary to the initial hypothesis

that defects would be most detrimental. Lean Six Sigma (LSS) tools—particularly a recommendation plan and 5S—were implemented to minimize waste. The proposed solutions led to a 4.79% increase in process cycle efficiency (from 66.19% to 70.98%), reduced cycle time (from 0.498 s/pcs to 0.486 s/pcs), significantly decreased lost time (from 194 to 87 minutes), defective products (from 25,146 to 12,508 pieces) and enhanced business performance.

Siddiqui and Iqbal (2021) employed a survey-based research strategy to investigate the impact of Six Sigma practices on organizational performance in Karachi, Pakistan. Primary data were collected through structured questionnaires distributed to professionals in the supply chain and quality enhancement departments of selected Six Sigma-adopting firms. The study found that Six Sigma implementation significantly contributed to enhancement of company performance by reducing costs, eliminating waste, and improving product and service quality as well as customer satisfaction. Importantly, the analysis also revealed that continuous improvement serves as a mediating variable in the relationship between the operational improvements (cost reduction, quality enhancement, and waste elimination) and overall company performance. This finding highlighted the role of continuous improvement as a critical mechanism through which Six Sigma practices translate into sustainable performance gains.

Bulla and Fogla (2023) presented extensive empirical evidence on the positive impact of Lean Six Sigma (LSS) across various industries, drawing from multiple case studies involving globally recognized firms such as General Electric, Motorola, Honeywell, Tata Motors, Infosys, and Indian Oil Corporation Limited (IOCL). The findings consistently demonstrate that the implementation of LSS methodologies leads to significant improvements in process efficiency, product quality, customer satisfaction, and cost reduction. These case studies highlighted the practical benefits and measurable performance gains associated with LSS adoption. The study emphasized the importance of adopting a holistic view of LSS, positioning it not only as a process improvement tool but as a strategic framework for achieving organizational excellence. The study concluded that organizations that integrate LSS principles into their operational systems are found to develop a culture of continuous improvement, resulting in sustained improvements in operational and overall organizational performance.

Adeodu et al. (2021) focused their empirical investigation on the optimization of production processes in a manufacturing setting, using Lean Six Sigma as the core improvement framework. The researchers applied tools such as the Pareto Chart, Root Cause Analysis (RCA), 5S, Single-Minute Exchange of Die (SMED), and Standard Operating Procedures (SOPs) within a paper manufacturing company to reduce downtime and increase Overall Equipment Effectiveness (OEE). Using the DMAIC approach, the study methodically diagnosed sources of inefficiency—particularly equipment-related delays—and implemented targeted solutions that led to measurable gains in production thorough put, cycle time reduction, and quality consistency. Their findings confirmed that Lean Six Sigma is not only applicable in large-scale industrial settings but also highly effective in medium-scale manufacturing environments with resource constraints. The authors underscore the importance of employee involvement and standardization in sustaining business performance improvements.

Akpan et al. (2023) conducted a study to examine the analyze-phase of six sigma and performance of manufacturing companies in the south eastern part of Nigeria. The study population comprised of 3565 management, senior and junior staff working in selected manufacturing concerns in South East Nigeria. The sample size of 347 was determined using Freund and William's statistical formula. The study adopted stratified sampling technique while structured questionnaire was used as instrument of data collection. Test retest and Cronbach's Alpha techniques were used to

determine the instrument reliability. Primary data collected were statistically tested using regression analysis at 5% significance level through SPSS version 23. The study found that: continuous improvement process has a positive significant effect on customer repurchase behaviour; being customer-centric has positive significant effect on profitability; elimination of wastes has significant positive effect on company's products quality; leader development has significant positive effect on reduction of expenses; and control process has significant positive effect on organizational performance. The study concluded that the analyze phase of six sigma has a significant positive effect on performance of food and beverage manufacturing firms in South East, Nigeria.

Nnabuife & Itua (2021) conducted a study to evaluate relationship between six sigma and performance of brewing firms in South South, Nigeria anchoring the study on The Theory of Constraints propounded by Goldraft (1984). Expost-facto research design was adopted and secondary data extracted from annual financial reports of the companies under study namely: Guinness Nigeria Plc, Champion Brewery and International Brewery Plc. The data collected were analyzed using regression analysis. The results revealed that a significant positive relationship exit between quality input and profitability. The study concluded that there is a strong positive significant relationship between six sigma and performance of the companies under study.

Okafor et al. (2018) carried out a study to determine the effects of six sigma on the performance of medium scale firms operating in South East Nigeria. The result of Pearson Product Moment Correlation analysis showed that: process definition practice has significant influence on customer patronage; process measurement has significant influence of positioning while process improvement significantly influenced customer retention among medium scale firms in South East, Nigeria. The study concluded that six sigma practices adoption by medium scale firms in South East has positive influence on performance of the firms studied.

Achibat et al. (2023) investigated the impact of Six Sigma and Lean Manufacturing on the performance of companies across various sectors in Morocco. Data were collected through questionnaires distributed to multiple companies, with 45 valid responses analyzed. The study assessed company performance on two dimensions: financial and operational. Using SPSS for statistical analysis, the researchers found that organizations implementing both Six Sigma and Lean Manufacturing reported significantly higher performance levels compared to those employing only Lean Manufacturing or neither methodology. The findings suggest that the integration of Six Sigma with Lean Manufacturing serves as a superior strategy for continuous improvement, yielding measurable enhancements in both financial outcomes and operational efficiency. This empirical evidence underscores the synergistic benefits of combining these two quality management approaches for sustainable organizational performance.

Frau et al. (2022) examined the sustainability implications of applying Lean Six Sigma tools within SMEs. Their empirical work involves a longitudinal study of multiple small enterprises in the food storage and distribution sector. They employ LSS interventions such as 5S, root cause analysis, and defect tracking systems to monitor changes in waste reduction, process time, and customer satisfaction. Results indicated a strong correlation between LSS adoption and enhanced resource utilization, reduced operational costs, and improved environmental outcomes. Additionally, the study reported a measurable increase in customer satisfaction due to consistent quality and timely delivery. Frau et al. argued that the strategic integration of LSS supported not just profitability but also the development of sustainable business models that align with the principles of circular economy and corporate social responsibility.

Madhani (2022) investigated the application of Continuous Improvement (CI) methodologies—specifically Lean, Six Sigma, and Lean Six Sigma (LSS)—within the retail sector, in response to increasing competitive pressures for higher quality standards, customer satisfaction, and financial performance. The study introduced the LSS Efficiency-Effectiveness (E-E) framework, aimed at exploring how LSS-induced drivers of efficiency and effectiveness impact overall retail business performance. The findings suggest that LSS methodologies facilitate measurable improvements in customer-centric processes, operational precision, and cost-effectiveness, thereby offering sustainable competitive advantage. The study concluded that successful LSS implementation transforms not only operational capabilities but also the strategic positioning of retail businesses in a highly competitive market environment.

The empirical study by Smith Hoces-Antesana and Guerrero-Villa (2024) investigated operational inefficiencies and high defect rates among small and medium-sized enterprises (SMEs) in the essential food storage sector, with a focus on Latin America and Peru. Using a Lean Six Sigma (LSS) framework integrated with 5S, Poka Yoke, and Standardized Work, the authors conducted a case study to evaluate the model's effectiveness in improving productivity and reducing waste. The results demonstrated notable operational gains: compliant activities improved from 63.3% to 70% with 5S, defects were reduced by 59%, packaging time by 34% through Poka Yoke, and operation times decreased by an average of 48% with Standardized Work, alongside a 36% reduction in product waste. The research offers strong empirical evidence supporting the application of LSS tools in SMEs, suggesting these methods enhance competitiveness, profitability and sustainability.

Ahmed et al. (2020) examined the mediating role of strategic thinking in the relationship between Six Sigma implementation and the operational performance of tourism companies in Iraq. The study employed a quantitative research approach, surveying 47 tourism companies and analyzing the data using Structural Equation Modelling (SEM). The results revealed that strategic thinking significantly enhanced the impact of Six Sigma on operational performance. Specifically, the integration of strategic thinking with Six Sigma practices was found to contribute to more efficient and effective processes. This synergy led to improved product and service quality, heightened customer satisfaction, and overall enhancement in operational performance. The study provided empirical evidence that strategic thinking is a critical component for maximizing the benefits of Six Sigma methodologies in the service sector, particularly in tourism-related enterprises.

Erdil (2021) explored the development, implementation, and impact of Six Sigma principles across diverse industries, focusing on its advantages, customer satisfaction outcomes, and common deployment challenges. The study provided a comprehensive overview of the Six Sigma organizational structure and emphasized key factors influencing successful adoption. The research highlighted that Six Sigma is now applied in various functional areas including marketing, finance, operations, regulatory compliance, and employee relations. The findings underline the importance of strong managerial involvement and proper methodological deployment for success. Additionally, the study points to future directions for refining Six Sigma frameworks to better align with evolving industry needs.

Mwenda et al. (2023) analysis of the operational difficulties faced by small and medium-sized enterprises (SMEs) in the food storage sector, emphasizing how these challenges significantly impede their efficiency and market performance. According to the study, issues such as poor process standardization, high defect rates, inefficient inventory management, and inadequate quality control mechanisms contributed to delays, increased costs, and resource wastage. These operational inefficiencies not only reduce the profitability of SMEs but also compromised their

ability to meet customer expectations and regulatory standards. As a result, SMEs struggle to maintain a competitive edge in an increasingly demanding and quality-driven market. Furthermore, the lack of structured improvement methodologies, such as Lean and Six Sigma, often prevents these businesses from identifying and addressing root causes of inefficiency.

The above literature review revealed that studies on six sigma are unpopular in Nigeria. This has resulted into limited literature on six sigma as it relates to Nigerian situation. Most of the studies on six sigma as reported were carried out in other continents of the world with little participation of African countries. Regarding Nigeria situation, majority of studies reported in literature were conducted with manufacturing companies in South East, Nigeria to the exclusion of other regions. Also, most of these studies concentrated on the overall effect of six sigma on performance with emphasis on financial performance (Akpan, et al., 2023; Nnabuife & Itua, 2021; Ogunwolu et al., 2021; Daniel, 2019; Okafor et al., 2018). Not many studies have been reported on examining the actual effect of each of the dimensions of six sigma on performance with focus on customer patronage as performance indicator.

Given the above literature, specific hypotheses are developed as follows:

$H_0$1 Application of Process definition principles has no significant effect on performance.

$H_0$2 Application of Process measurement principles has no significant effect on performance.

$H_0$3 Application of Process diagnostics principles has no significant effect on performance.

$H_0$4 Application of Process improvement principles has no significant effect on performance.

$H_0$5 Application of Process control principles has no significant effect on performance.

$H_0$6 Application of Six sigma principles has no significant effect on performance.

## 3. METHODOLOGY

The study is anchored on total quality management theory that emphasizes on product quality and customer satisfaction which are the major thrusts of six sigma methodology as conceptualized in this study. Cross-sectional survey research design is adopted. The population of the study consists of all the small sized manufacturing industries in Abuja. SMEDAN estimated that about 1% (4,825) of the four hundred and eighty-two thousand, three hundred and sixty-five (482,365) small and medium enterprises that are registered with SMEDAN Abuja (Njoku, et al, 2022) are small scale manufacturing firms (SMEDAN, 2024). The sample size was determined as 370 using Yamane (1967) formula. The research instrument is structured questionnaire. It consists of three sections namely: demography and company's information (seven items), Six Sigma with all the dimensions - process description, process measurement, process diagnostic/analysis, process improvement and process control (twenty items) and business performance (ten items). The questions were presented on a Six-point Likert scale. The validity of the research instrument was evaluated by a panel of experts comprising academic researchers, practitioners in entrepreneurship, and other specialists to ensure accuracy as well as ensuring that the research instrument measures accurately the different dimensions of the study. Feedbacks received from the experts were used to modify some items on process diagnostics, process improvement and business performance. The reliability of the instrument was examined through pilot study. Thirty seven questionnaires (10% of sample size) were pretested through face to face questionnaire administration technique to identified small scale manufacturing firms in Nasarawa State. Upon analysis using SPSS Version 26, the overall Cronbach's Alpha value of 0.718 for the questionnaire indicated that the research instrument is reliable since it is greater than 0.7 (Keith, 2018). Three hundred and seventy (370) questionnaires were administered electronically using Goggle form to respondents with the assistance of the office of Small and Medium Enterprise Development Agency (SMEDAN). The

data collected were analyzed with the aid of Statistical Package for Social Sciences i.e., SPSS Version 26.

## 4. RESULTS AND DISCUSSION

### 4.1 Hypothesis: $H_0$1.

**$H_0$1** Application of Process Definition principles has no significant effect on Performance.

**Table 1: Effect of application of Process Definition Principles on Performance**

| Variables | B | Std. Error | Beta (β) | T | R | $R^2$ | F | Df (residual) | P Sig |
|---|---|---|---|---|---|---|---|---|---|
| (Constant) | 34.555 | 1.819 | | 19.008 | | | | | 0.000 |
| Process Definition | .669 | .106 | .404 | 6.291 | .404 | .163 | 39.574 | 1(203) | 0.000 |
| **Dependent Variable: Performance** | | | | | | | | | |

Source: Field Survey 2025. Note: β = Standardized Coefficient, Significant at 0.05

Table 1 indicates that application of process definition principles has a significant effect on performance ($R^2$= 0.163, $F_{(1,203)}$ = 39.574,$p$ = 0.000< 0.05) with application of process definition principle having a moderate positive but significant effect on performance *(*$R$= 0.404; $p$<0.05). This explained 16.3% (Adj$R^2$= .163) variation performance while the remaining 83.7% is attributed to other factors not captured in the model. The regression model showed that holding process definition principles at a constant zero, performance would be 34.555, indicating a baseline level of performance independent of application of process definition principles. The linear regression results suggest that for every one-unit increase in application process definition principles, performance will improve by 0.404. Consequently, the null hypothesis ($H_0$1), which states that application of process definition principles has no significant effect on performance of medium scale manufacturing industry in Abuja, is rejected.

### 4.2 Hypothesis: $H_0$2

**$H_0$2** Application of Process Measurement principles has no significant effect on Performance.

**Table 2: Effect of Application of Process Measurement Principles on Performance**

| Variables | B | Std. Error | Beta (β) | T | R | $R^2$ | F | Df (residual) | P Sig. |
|---|---|---|---|---|---|---|---|---|---|
| (Constant) | 36.274 | 1.933 | | 18.762 | | | | | 0.000 |
| Process Measurement | .548 | .109 | .332 | 5.012 | .332 | .110 | 25.121 | 1(203) | 0.000 |
| Dependent Variable: Performance | | | | | | | | | |

Source: Field Survey 2025. Note: β = Standardized Coefficient, Significant at 0.05

Table 2 indicates that application of process measurement principles has a significant effect on the performance ($R^2$= 0.110, $F_{(1,203)}$ = 25.121,$p$ = 0.000< 0.05). Application of process measurement principles has a moderate positive but significant effect on performance *(*$R$= 0.332; $p$<0.05). It

explained 11% ($R^2$= .110) variation in performance while the remaining 65.4% is attributed to other factors not captured in the model. The regression model showed that holding application of process measurement principles at a constant zero, performance would be 36.274, indicating a baseline level of performance independent of application of process measurement principles. The linear regression results suggest that for every one-unit increase in process measurement, performance will improve by 0.332. As a result of this, the null hypothesis ($H_0$2), which states that application of process measurement principles has no significant effect on performance of small scale manufacturing industry in Abuja, is rejected.

### 4.3 Hypothesis: $H_0$3:

$H_0$3 Application of Process Diagnostics principles has no significant effect on Performance.

**Table 3: Effect of Application of Process Diagnostic on Performance**

| Variables | B | Std. Error | Beta (β) | t | R | $R^2$ | F | Df (residual) | P Sig. |
|---|---|---|---|---|---|---|---|---|---|
| (Constant) | 36.128 | 1.585 | | 22.788 | | | | | 0.000 |
| Process diagnostic | .572 | .092 | .401 | 6.233 | .401 | .161 | 38.853 | 1(203) | 0.000 |
| **Dependent Variable: Performance** | | | | | | | | | |

Source: Field Survey 2025 , Note: β = Standardized Coefficient, Significant at 0.05

Table 3 indicates that application of process diagnostic principles has a significant effect on performance ($R^2$= 0.161, $F_{(1,203)}$ = 38.853,$p$ = 0.000< 0.05) with result showing that application of process diagnostic principles has a moderate positive but significant effect on performance *(*$R$= 0.401; $p$<0.05). This explained 16.1% ($R^2$= .161) variation in performance while the remaining 83.9% is attributed to other factors not captured in the model. The regression model showed that holding application of process diagnostic principles at a constant zero, performance would be 36.128, indicating a baseline level of performance independent of process diagnostic. The linear regression results suggest that for every one-unit increase in application of process diagnostic principles, performance will improve by 0.401.Therefore, the null hypothesis ($H_0$3), which states that application of process diagnostic principles as no significant effect on performance of medium scale manufacturing industry in Abuja, is rejected.

### 4.4 Hypothesis: $H_0$4:

**$H_0$**4 Application of Process Improvement has no positive and significant effect on Performance.

**Table 4: Effect of Application of Process Improvement Principles on Performance**

| Variables | B | Std. Error | Beta (β) | T | R | $R^2$ | F | Df (residual) | P Sig. |
|---|---|---|---|---|---|---|---|---|---|
| (Constant) | 31.400 | 1.766 | | 17.777 | | | | | 0.000 |
| Process Improvement | .825 | .100 | .502 | 8.277 | .502 | .252 | 68.506 | 1(203) | 0.000 |
| **Dependent Variable: Performance** | | | | | | | | | |

Source: Field Survey 2025 , Note: β = Standardized Coefficient, Significant at 0.05

Table 4 1indicates that application of process improvement principles has a significant effect on performance ($R^2$= 0.252, $F_{(1,203)}$ = 31.400,$p$ = 0.000< 0.05). Application of process improvement principles has a moderate positive but significant effect on performance *(*$R$= 0.502; $p$<0.05). This

explained 25.2% ($R^2$= .252) variation in performance of medium scale manufacturing industry in FCT Abuja while the remaining 74.8% is attributed to other factors not captured in the model. The regression model shows that holding application of process improvement principles at a constant zero, performance would be 31.400, indicating a baseline level of performance independent of process improvement principles. The linear regression results suggest that for every one-unit increase in application of process improvement principles, performance will improve by 0.502. Therefore, the null hypothesis ($H_0$4), which states that application of process improvement principles has no significant effect on performance of medium scale manufacturing industry in Abuja, is rejected.

### 4.5 Hypothesis: $H_0$5:

**$H_0$**5 Application of Process Control principles has no significant effect on Performance.

**Table 5: Effect of Application of Process Control Principles on Performance**

| **Variables** | **B** | **Std. Error** | **Beta (β)** | **t** | **R** | **$R^2$** | **F** | **Df (residual)** | **P Sig.** |
|---|---|---|---|---|---|---|---|---|---|
| (Constant) | 36.000 | 1.645 | | 21.884 | | | | | 0.000 |
| Process Control | .594 | .098 | .392 | 6.080 | .392 | .154 | 36.965 | 1(203) | 0.000 |
| **Dependent Variable: Performance** | | | | | | | | | |

Source: Field Survey 2025. Note: β = Standardized Coefficient, Significant at 0.05

Table 5 indicates that application of process control principles has a significant effect on performance ($R^2$= 0.154, $F_{(1,203)}$ = 36.965,$p$ = 0.000< 0.05) with application of process control principles having a moderate positive but significant effect on performance *(*$R$= 0.392; $p$<0.05). Process control principles explained 15.4% ($R^2$= .154) variation in performance while the remaining 84.6% is attributed to other factors not captured in the model.

The regression model shows that holding process control principles at a constant zero, performance would be 36.000, indicating a baseline level of performance independent of process control principles. The linear regression results suggest that for every one-unit increase in application of process control principles, performance will improve by 0.392.Consequently, the null hypothesis ($H_0$5), which states that application of process control principles has no significant effect on performance of medium scale manufacturing industry in Abuja, is rejected.

### 4.6 Hypothesis: $H_0$6:

**$H_0$**6 Application of Six sigma principles has no significant effect on performance.

**Table 6: Effect of Six Sigma and Performance**

| Variables | B | Std. Error | Beta (β) | T | R | Adj. $R^2$ | F | Df | P | Sig. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| (Constant) | 24.524 | | | 11.433 | | | 22.927 | 5(199) | 0.000 | |
| Process Definition | 0.587 | 0.104 | 0.354 | -2.003 | 0.605 | 0.350 | | | 0.047 | 0.047 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Process Measurement | 0.280 | 0.140 | -0.169 | 5.632 | | | | | 0.000 | 0.000 |
| Process Diagnostics | 0.138 | 0.131 | -0.097 | -1.050 | | | | | 0.295 | 0.295 |
| Process Improvement | 0.806 | 0.144 | 0.491 | 5.580 | | | | | 0.000 | 0.000 |
| Process Control | 0.273 | 0.137 | 0.180 | 1.997 | | | | | 0.047 | 0.047 |

Dependent Variable: Performance
Source: Field Survey 2025. Note: β = Standardized Coefficient, Significant at 0.05

Table 6 indicates that application of Six sigma principles has a positive significant effect on performance with six sigma principles having a significant effect on performance ($Adj.R^2$= 0.350, $F_{(5,199)}$= 22.927,$p$ = 0.000< 0.05). The F-statistic indicating that the overall model is significant, reinforcing the importance of both Six sigma principles influence performance. This suggests that the multiple linear combinations of Six sigma principles would improve performance. The analysis showed that six sigma principles explained 35% ($Adj.\ R^2$= .350) variation in performance while the remaining 65% is attributed to other factors not captured in the model. The overall model is statistically significant as shown by the F-statistic. This confirmed that the combination of Six Sigma dimensions significantly predicts performance.

However, looking at the individual contribution to performance in the combined model, applications of process measurement principles (β = 0.280, t = 5.632, p = 0.000), process improvement principles (β = 0.806, t = 5.580, p = 0.000), and process control principles (β = 0.273, t = 1.997, p = 0.047) have significant positive and significant effects on performance, all with p-values below 0.05. On the other hand, application of process definition principles (β = 0.587, t = -2.003, p = 0.047) in the combined model showed a statistically significant but negative effect on performance. Similarly, application of process diagnostics principles (β = 0.138, t = -1.050, p = 0.295) was not statistically significant, indicating it did not contribute meaningfully to explaining performance outcomes in the combined model. The constant value of 24.524 implies that in the absence of any Six Sigma interventions, the expected baseline performance score would be 24.524. Overall, the hypothesis ($H_0$6) that application of Six Sigma has no significant effect on performance is rejected, affirming that Six Sigma practices—particularly measurement, improvement, and control are essential predictors of performance.

The resulting model (Fig. 1) presents the outcomes of the relationships between the variables and incorporates key statistical findings that highlight the significance of the hypotheses guiding the study.

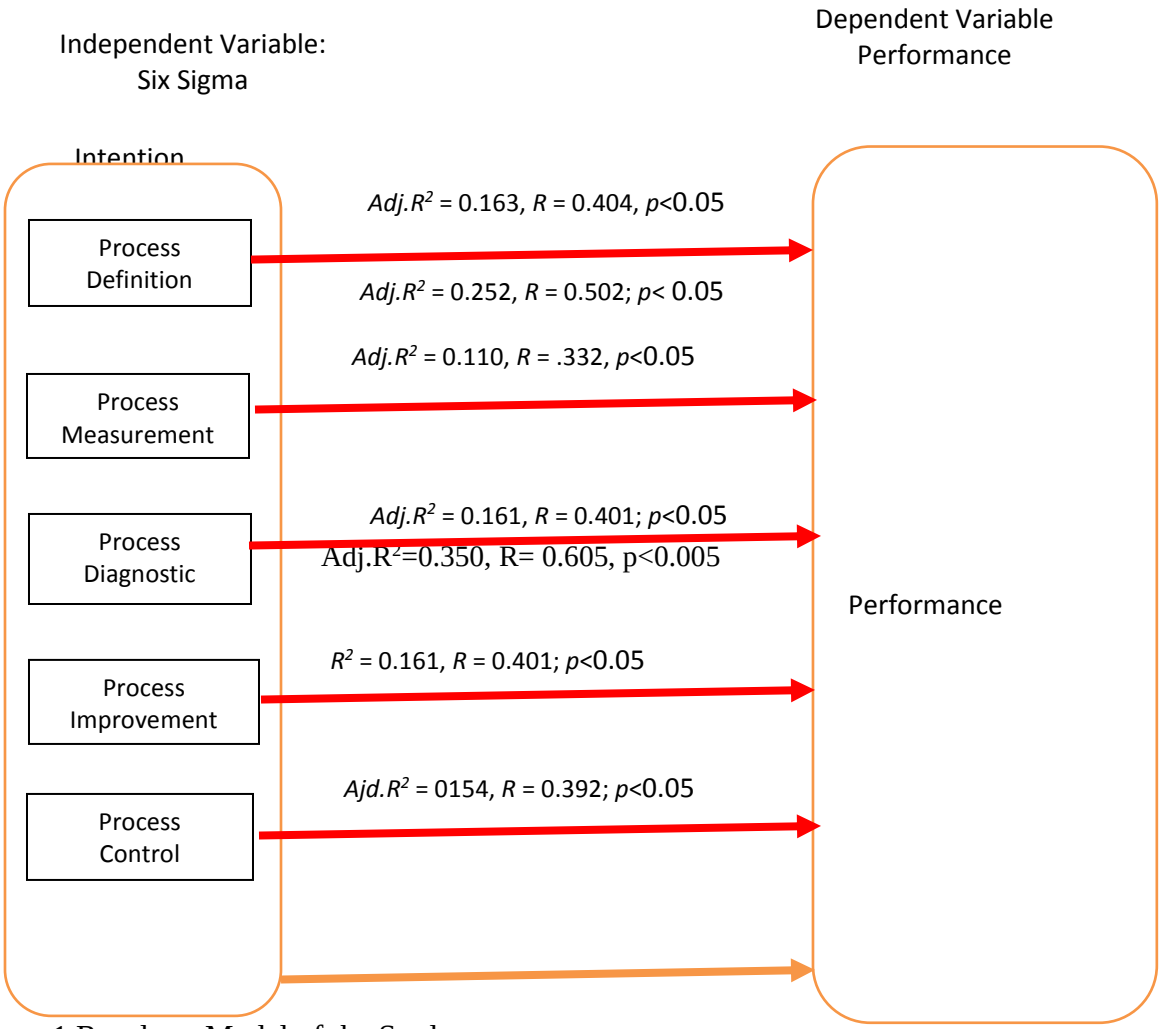


Figure 1 Resultant Model of the Study

## 4.7 DISCUSSION

The findings revealed that application of process definition principles has a positive significant effect on the performance of small-scale manufacturing industries in FCT Abuja. Clearly articulated and well-aligned processes were associated with improved organizational outcomes. Respondents demonstrated strong adherence to Six Sigma principles, particularly in aligning processes with organizational goals and maintaining customer focus. However, the integration of customer perspectives during the initial stages of process definition was identified as a notable weakness, suggesting a critical area for improvement. This is in line with Siddiqui and Iqbal's (2021) study, which shows that Six Sigma practices contributed to enhanced company performance by reducing costs, eliminating waste, and improving quality—particularly when supported by continuous improvement mechanisms. Bulla and Fogla (2023) also affirmed that Six Sigma implementation improves process efficiency, product quality, and customer satisfaction, emphasizing the value of adopting it as a strategic framework rather than a technical tool. Similarly, Prabha and Yuvaraja (2022) found that integrating IoT technologies into Six Sigma

frameworks can strengthen process efficiency by improving the precision and responsiveness of data collection, especially in resource-constrained environments.

On the application of process measurement principles, the findings showed that application of process measurement principles has a positive and significant effect on the performance. Respondents demonstrated strong data-driven and customer-focused orientations, particularly in aligning benchmarks with customer expectations and evaluating current process levels. Nonetheless, variability was observed in the measurement of waste and reliance on stakeholder data, indicating a need for more standardized measurement protocols across firms. These findings aligned with Muhammad et al. (2022), who underscored the importance of structured measurement within the DMAIC framework in managing crises like the COVID-19 pandemic. Their study show that accurate process measurement enabled firms to adapt quickly, minimize waste, and sustain operational efficiency even under volatile conditions—demonstrating measurement's pivotal role in strategic resilience. Similarly, Adeodu et al. (2021) provided empirical evidence on the effectiveness of Lean Six Sigma tools, such as SOPs and Root Cause Analysis, in identifying and addressing inefficiencies. Their results reinforce the idea that consistent and targeted process measurement is essential for reducing downtime, enhancing cycle time, and improving overall quality in production environments. In addition, Albayatey (2023) emphasized the value of critical success factors in Six Sigma implementation, including effective measurement mechanisms.

The study revealed that application of process diagnostics principles significantly enhanced performance, with respondents demonstrating moderate to high adoption of diagnostic practices such as reducing defect rates, conducting failure analysis, setting measurable goals, and utilizing historical data to guide improvements. This consistent yet evolving engagement with systematic diagnostics aligned with findings by Achibat et al. (2023), who showed that combining Six Sigma with Lean Manufacturing substantially improved operational and financial performance by emphasizing diagnostic precision within broader lean practices. Similarly, Reardon et al. (2021) found that Lean and Six Sigma methodologies reduced defects and improved operational efficiency in food-related SMEs, contributing not only to firm productivity but also to regional economic stability and supply chain resilience. Khalid (2024) highlighted the societal benefits of diagnosing operational inefficiencies in SMEs, demonstrating that quality improvements driven by diagnostics enhance service delivery and supply chain reliability in resource-constrained and crisis-prone environments, reinforcing the foundation of performance improvement established in this study. Furthermore, Frau et al. (2022) confirmed the sustainability advantages of Lean Six Sigma diagnostics through a longitudinal study, noting improvements in waste reduction, resource utilization, and customer satisfaction, which supported both operational gains and broader corporate social responsibility goals. Collectively, these findings underscore the critical role of process diagnostics as a key driver of improved performance, competitiveness, and sustainable development in manufacturing and related sectors.

Regarding the application of process improvement principles, application of process improvement principles significantly enhanced performance. Respondents showed a strong commitment to customer satisfaction as the core focus of their improvement efforts. While there was consistent agreement on the positive impact of improvements on customer experience, testing solutions before implementation, and aligning improvements with performance goals, these practices were not uniformly adopted. Supporting this, Mandhani (2022) found that Lean Six Sigma methodologies improved operational efficiency, customer satisfaction, and cost-effectiveness in the retail sector, helping businesses gain a sustainable competitive advantage. Similarly, Smith

Hoces-Antesana and Guerrero-Villa (2024) demonstrated that Lean Six Sigma tools such as 5S and Poka Yoke significantly reduce defects, waste, and operational times in SMEs, boosting productivity and sustainability. Additionally, Nedra et al. (2022) emphasized that ISO 9001 certification strengthened Lean Six Sigma implementation by enhancing process control and fostering a culture of continuous improvement. This suggests that standardized practices supported by recognized quality frameworks can further improve operational reliability and efficiency in essential product industries.

The study revealed that application of process control principles are moderately implemented among small-scale manufacturing firms in FCT Abuja, with respondents recognizing the importance of application of process control principles in sustaining customer satisfaction, monitoring plans, issue mitigation, and validating measurement systems, although application levels vary across firms. The analysis further showed that application of process control principles has a significant positive effect on firm performance, confirming a moderate and statistically significant effect. Supporting these findings, Ahmed et al. (2020) demonstrated that strategic thinking enhances the impact of Six Sigma implementation on operational performance in Iraq's tourism sector by improving efficiency, product quality, and customer satisfaction. Erdil (2021) provided a broader perspective on Six Sigma's application across industries, emphasizing that strong managerial involvement and proper methodology are crucial for successful adoption, while Wassan et al. (2022) identified critical success factors for Lean and Six Sigma implementation in SMEs, including top management commitment, employee involvement, training, communication, and a culture of continuous improvement. These studies collectively underscored the importance of structured process control practices supported by strategic and managerial frameworks to optimize performance in diverse operational contexts.

The findings highlighted the effect of six sigma on business performance with results showing that six Sigma significantly enhanced performance through process measurement, process improvement, and process control. These align closely with Dumitrascu et al. (2025), who demonstrated that Six Sigma's structured approach, including process measurement and improvement, reduced defect occurrences in industrial parts manufacturing, enhancing product quality and operational performance. Similarly, Mittal et al. (2023) found that the Process Improvement phase of Six Sigma's DMAIC methodology significantly lowered rejection rates in rubber weather strip production, improving cost efficiency and customer satisfaction. Both studies underscore the pivotal role of process measurement and improvement, as seen in the Abuja findings, where these variables were key drivers of performance, reinforcing Six Sigma's capacity to deliver measurable business outcomes through targeted quality enhancements.

However, the observation that process definition negatively impacts performance and process diagnostics in the combined model of the five dimensions of six sigma lacks significance presents a nuanced contrast with the cited studies. Maia et al. (2024) suggested that structured Six Sigma processes, including diagnostic elements enhanced by Big Data analytics, positively influence business performance in Brazilian manufacturing by improving decision-making and quality perception. This contrasts with the findings of this study, where process diagnostics showed no meaningful contribution in the combined model, possibly due to limited data integration or diagnostic tool application in the local context. Taneo et al. (2020) further emphasized the value of diagnostic tools like root cause analysis in SMEs, which, when paired with process improvement, reduced defects at a faster rate and optimized resources, suggesting that effective diagnostics could enhance performance if better implemented. The negative effect of application

of process definition in the combined model may reflect unclear scoping or misalignment with business goals, a challenge not explicitly addressed in the cited studies but implied in their emphasis on precise process alignment.

The collective insights suggest that Six Sigma's impact on business performance is maximized when its variables are cohesively applied, though contextual factors influence outcomes. Therefore, the study collectively affirm Six Sigma's potential to enhance business performance but underscore the need for tailored application to address local constraints, ensuring all variables, including diagnostics and definition, contribute positively to quality and efficiency outcomes.

## 5 CONCLUSION AND RECOMMENDATION

The study concluded that application of Six Sigma principles has a significant effect on the performance of small-scale manufacturing industries in Abuja with the combined dimensions having more effect on performance than when each dimension is applied individually. However, in the combined dimension only process improvement, process measurement and process control made significant contributions to performance whereas process definition and process diagnostics did not. The results concluded that when companies use these three aspects or dimensions of Six Sigma well they can greatly improve their overall performance.

Since the findings of the study showed that application of six sigma principles has positive and significant effect on performance, it is recommended that the studied firms should implement six sigma tools in their manufacturing concern to enhance performance while specific attention should be given to process measurement, process improvement and process control tools for optimal performance. The firms could engage the services of management consultants who are experts six sigma to implement six sigma tools in their firms.

## REFERENCES

Adeodu, A. O., Kanakana-Katumba, M. G., & Maladzhi, R. (2020). Implementation of Lean Six Sigma (LSS) methodology through DMAIC approach to resolve downtime process: A case of a paper manufacturing company. In *Proceedings of the 2nd African International Conference on Industrial Engineering and Operations Management* (pp. 37–47). http://ieomsociety.org/harare2020/papers/9.pdf

Adeodu, A., Kanakana-Katumba, M., & Maladzhi, R. (2021). Implementation of Lean Six Sigma for production process optimization in a paper production company. *Journal of Industrial Engineering and Management, 14*(3), 661–676. https://doi.org/10.3926/jiem.3479

Ahmed, A. A., Ahmed, S. I., & Atiyah, S. M. (2020). Impact of Six Sigma methodology and strategic thinking on operational performance of tourism operations. *African Journal of Hospitality, Tourism and Leisure, 9*(2), 1-17. http://www.ajhtl.com

Akpan, I.G., Chukwu, B.I., Ameali, C.C., & Onyemachi, C.A (2023). Analyse-phase of Six sigma and performance of manufacturing firms in South East , Nigeria. *Innovations*, 75, 926-940.

Albayatey, A. S. W. (2023). Critical success factors for applying Six Sigma in transformative industries in Iraq. *International Journal of Professional Business Review, 8*(6), 1–15. https://doi.org/10.26668/businessreview/2023.v8i6.1917

Antony, J., et al. (2023). Critical success factors for the effective implementation of Six Sigma in pharmaceutical manufacturing. *International Journal of Quality & Reliability Management, 40*(5), 1234–1252.

Antony, J., McDermott, O., Powell, D., & Sony, M. J. T. T. J. (2022). The evolution and future of lean Six Sigma 4.0. *The TQM Journal*, 35(4). https://doi.org/10.1108/TQM-04-2022-0135.

Bulla, N., & Fogla, A. (2023). The impact of Lean Six Sigma on organizational performance. *International Journal of Science, Technology and Management, 10*(1), 1-6.

Chakote, A., Chougale, O., Patil, S., & Malakane, A. (2025). Six sigma in pharmaceutical industry-A comprehensive review. International Journal of Pharmaceutical Sciences, 3(5), 2222-2234.

Daniel, C.O. (2019). Impact of Six Sigma strategy on the performance of selected manufacturing firms in Nigeria. *Global Scientific Journal*, 7(1), 272-279.

Daniyan, I., Adeodu, A., Mpofu, K., Maladzhi, R., Mukondeleli, Katumba, K. (2022). "Application of lean Six Sigma methodology using DMAIC Approach for the improvement of bogie assembly process in the railcar industry", *Heliyon*, Science Direct, 8(3), 1–14.

Dumitrascu, DI., Rusu, AN., Dumitrascu, AE. (2025). The Improvement of Industrial Products Quality Through Six Sigma Method Implementation. In: Rackov, M., Miltenović, A., Banić, M. (eds) Machine and Industrial Design in Mechanical Engineering. KOD 2024. Mechanisms and Machine Science, 174. Springer, Cham. https://doi.org/10.1007/978-3-031-80512-7_82

Fahimi, K and Amirabadi, M. (2024). Applying Six Sigma methodology to improve performance in organizations. *Int. J. Hum. Capital Urban Manage*ment, 9(3): 537-552

Farida, I., & Setiawan, D. (2022). Business strategies and competitive advantage: The role and performance and innovation. *J. Open Innov. Technol. Mark. Complex*, 8(3), 163. https://doi.org/10.3390/joitmc8030163

Ghelani, H.J. (2024). Six sigma and continuous improvement strategies: A comparative analysis of global manufacturing industries. International Journal of Scientific Research and Management, 11(08), 954-972. DOI: 10.18535/ijsrm/v11i08.ec05

Gupta, A., Sharma., P., J., A., Xue, H., Malik, S.C., & Jha, P.C. (2023). An integrated DEMATEL Six Sigma hybrid framework for manufacturing process improvement. *Annals of Operations Research*, 322(2), 713-753. DOI:10.1007/s10479-019-03341-9.

Gupta, V., Jain, R., Meena, M.L., & Dangayach, G.S. (2018). Six-sigma application in tire-manufacturing company: a case study. *J Ind Eng Int*, 14(3), 511–520. https://doi.org/10.1007/s40092-017-0234-6

Hoces-Antesana, K. S., & Guerrero-Villa, C. D. (2024, October 9–11). *Implementing Lean Six Sigma to enhance operational efficiency and reduce waste in essential food storage SMEs: A case study*. In Proceedings of the 1st World Congress on Industrial Engineering and Operations Management (Paper No. WC01.20240026). IEOM Society International. https://doi.org/10.46254/WC01.20240026

Keith, S.B. (2018). The Use of Cronbach's Alpha When Developing and Reporting Research Instrument in Science Education. *Research in Science Education*, 48(1), 1-24.

Khalid, N. (2024). Sanitation knowledge and practices of malaysian food smes: addressing current issues and readiness in acceptance of green sanitation technology. International *Journal on Advanced Science Engineering and Information Technology*, 14(1), 181-188. https://doi.org/10.18517/ijaseit.14.1.1830

Laureani, A., & Antony, J. (2023). Six Sigma in retail: Improving inventory management for operational excellence. *Journal of Service Management, 34*(4), 789–805.

Martínez-Lorente, A. R., Dewhurst, F., & Dale, B. G. (1998). Total quality management: Origins and evolution of the term. *The TQM Magazine, 10*(5), 378–386. https://doi.org/10.1108/09544789810231261

McDaniel, D. M., & Doherty, L. M. (1990). *Total quality management case study in a Navy headquarters organization* (Report No. NPRDC-TN-90-10). Navy Personnel Research and Development Center. https://apps.dtic.mil/sti/pdfs/ADA227755.pdf

Moses, P (2024). Why Manufacturing Sector's Contribution to GDP is still low-MAN. Daily Trust (Business New), November 1.

Murmura, F., Bravi, L., Musso, F., & Mosciszko, A. (2021). Lean Six Sigma for improvement of company processes: The Schnell S.p.A case study. *The TQM Journal*, 33(7), 351-376. DOI: 10.1108/TQM-06-2021-0196.

Mwenda, B.B., Ngollo, M., and Mwasota, A. (2023). An empirical study on the effects of managerial competence on firm profitability. *Ilomata International Journal of Tax and Accounting*, 4(3), 491-507. DOI: 10.52728/ijtc.v413.794

Nedra, A., Jun, X., Nejib, S., and Jiaji, D. (2022). Effect of ISO 9001 certification and article type produced on Lean Six Sigma application successes: A case study within textile companies. *Fibres & Textiles in Eastern Europe*, 151(12), 17-22. DOI:10.2478/ftee-2022-003.

Njoku, V. O., Ukaoha, C. A., Anthony, L., Ajibare, D. B., & Oluleye, O. D. (2022). Assessment of investment decisions and financial performance of small and medium enterprises in federal capital territory, Nigeria. *International Journal of Small and Medium Enterprises*, 5(1), 40–49. https://doi.org/10.46281/ijsmes.v5i1.1813

Nnabuife, E. & Itua, O.P. (2021). Six sigma manufacturing and performance of brewing firms in South-South, Nigeria. *European Journal of Business and Innovation Research*, 9(4), 41-55.

Ogunwolu, F.O., Odeyinka, O.F., & Oluwaji, O.A. (2021). A review of lean manufacturing, six sigma and lean six sigma. *The Pacific Journal of Science and Technology*, 22(1), 77-90.

Okafor, I.G., Agbaeze, E.K., Ekoja, G.O & Obamen, J. (2018). Effect of six sigma on performance of medium scale manufacturing firms in South Eastern Nigeria. *International Research Journal of Management, IT and Social Sciences*, 5(4), 26-45. DOI: 10.21744/irjmis.v5n4.253.

Okojie, J (2024). Nigeria's manufacturing investment hit year low as economic woes worsen. Business Day, July 8

Onwuamaeze, D (2024). Worrisome Drop in Manufacturing Contribution to GDP. ThisDay, September.

Ravindra L. Karwande(B), Santosh P. Bhosle, and Prashant M. Ambad (2023). A Review of Six Sigma Approach to Enhance Performance in Manufacturing Industries. In: S. Tamane et al. (Eds.): ICAMIDA 2022, ACSR 105, pp. 654–663. https://doi.org/10.2991/978-94-6463-136-4_56

Reardon, T., Liverpool-Tasie, L., & Minten, B. (2021). Quiet revolution by SMEs in the midstream of value chains in developing regions: wholesale markets, wholesalers, logistics, and processing. *Food Security*, 13(6), 1577-1594. https://doi.org/10.1007/s12571-021-01224-1

Ridwan, A., Sonda, A., & Amelia, A. (2023). Product quality control analysis using six sigma method. *Journal Industrial Services*, 9(1), 53-58.

Sabtu, S. (2024). Systematic literature review on the implementation of the Six Sigma approach in education. *International Journal of Evaluation and Research in Education, 13*(1), 262–270. https://doi.org/10.11591/ijere.v13i1.26196

Sengupta S, Chung DW, Kumar, R, Gupta P, Upadhyay S, Rattan A. (2024). Sigma metrics as quality indicators in guiding and tracking laboratory process improvement. *International Journal of Research in Medical Sciences,12*(1), 75-81. https://doi.org/10.18203/2320-6012.ijrms20233837

Setiawan, S.A (2025). Implementation of Six Sigma methodology to reduce high defect rate in rubber processing industry. *European Journal of Business Management Research,* 10(1), 118-126. https://doi.org/10.24018/ejbmr.2025.10.1.2538

SMEDAN (2024). Micro, Small and Medium Enterprises in Abuja. Internal Seminar SMEs Report, SMEDAN, Abuja Office.

Sodhi, H. S., et al. (2024). Lean Six Sigma in automotive supply chain: Enhancing delivery performance. *Production Planning & Control, 35*(8), 912–928

U-Dominic., C.M., Orji, I.J., Igbokwe, N.C., Onyeka, N.C., Nwufo, M.A. (2025). A decision methodology for six sigma implementation in the Nigerian small and medium scale enterprises, *Unizik Journal of Technology, Production and Mechanical Systems*, 5(1), 186-202.

Young, V.A (2024). Why Manufacturing Sector is in Crisis- NECA. Vanguard Newspaper, September 16,