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Process Innovation and Performance of Manufacturing Firms in Rivers state

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Abstract

This study examined Process Innovation and performance of manufacturing firms in Rivers state, Additive manufacturing (3D Printing) metrics and Lean - Six sigma performance dash board were used as dimension of process innovation while productivity was used as measure of performance of manufacturing firms in Rivers state. It adopted cross sectional research design with a. correlational inquiry type. The population used in the study was 850 permanent employees of 28 registered manufacturing firms residing in Rivers State whereas the sample size is 120 respondents. The stratified random sampling technique was used. A total of 120 copies of the questionnaire were handed out with survey method. Univariate and Bivariate inferential statistics of Pearson's Product Moment Correlation was adopted. Statistical Package for the Social Sciences (SPSS) version 23.0 was used to perform all of the statistical analyses. The findings suggest a very strong correlation between Additive manufacturing metrics, Lean-Six-Sigma performance dashboards and productivity in manufacturing firm in Rivers State. The study concluded that there is a positive and significant correlation relationship between process innovation and performance of manufacturing firms in Rivers State. It was recommended that (i). Managers of manufacturing firms in Rivers State should increase the use of Additive manufacturing (3D Printing) metrics, in order to increase productivity. ii. Management of manufacturing firms in Rivers State should regularly organise regular training for their employees in the use of Lean-Six-Sigma performance dashboards, a means of in-view of tracking product defect rates, cycle-time reduction and wastes perspectives. iii. Manufacturing firms in Rivers State need to utilise artificial intelligence (AI)-driven predictive Maintenance Metrics for efficient and unhindered production process.

Keywords: Manufacturing Firms, Process Innovation, and Performance.

1.0 Introduction

Performance is the bottom-line to any organisation, be it business or non-business. It is necessary because non-performance can be a recipe for failure. This study however focuses on the performance of manufacturing firms. Performance is a subjective measure of how well a firm is able to utilise assets from the main and non-main businesses activities in order to generate revenue (Investopedia., 2015). The term performance, is also used as a general measure of a firm's overall financial health over a given period of time, and can be used to compare similar firms across the same industry or to compare industries or sectors in aggregation.

There are many different ways to measure performance though all organisations have performance measures as part of their performance management practises and there is debate as to the relative importance of financial and non-financial indicators. Proponents of financial performance measures argue that they are needed in view of the main objectives of firms. Line items such as gross revenue from operations, operating income or cash flow from operations can be used as well as return on total assets. Performance exists in different levels of the organisation. Traditionally, performance measures here are divided into two categories - profitability, and productivity. This study is focused on the productivity of manufacturing firms which is valued by a firms increase in production.

Firms in this modern, demanding business environment are becoming more aggressive especially when seeking innovative ways to ensure their profitability and enjoy a long-term competitive advantage (Namusonge, Muturi & Olaniran, 2016; Sunday & Wobo, 2025; Sunday et al., 2019). According to Ebuzoeme, (2022); Faith and Simon (2023), process innovation is currently seen as a means of providing organisations with directions that will help them reduce the cost of unit production and delivery to the consumers while simultaneously increasing the quality of their products while introducing new goods. Increased level of innovation and technological improvement to manufacturing industries has been theorised to be correlated with competitiveness. These businesses must coordinate their efforts in order to enhance their effectiveness and standard of business operations (Alvarez, Bravo-Ortega & Zahler, 2015).

Process innovation is one of the key tools that manufacturing companies may use to enhance their expansion into new markets and gain a larger market share in markets where the company is already active giving the company a competitive edge over the rival companies (Kiptoo & Koech, 2019; Olulu-Briggs 2020; Olulu-Briggs & Orowhuo, 2024). However, due to the context within which businesses operate, where there is real competition and technological changes could easily erode the value offered by certain goods or services, this research stressed the need for innovation by Nnodim, Onuoha and Needorn,

(2020). Process innovation is helpful for reducing the cost to an organisation and usually leads to product innovation for introducing new products in the market. Domnich (2022) argues that companies that tightly integrate process innovation are more likely to be successful, especially in the attempts that it makes to increase performance. Iherobiem (2023) states that process innovation is a great improvement on the manufacturing and logistical processes as well as the acquiring and maintenance of the auxiliary operations of a firm. This is a strategy that allows the firms allow them to reduce the total cost of production in its manufacture process.

According to Nwankwo and Ezeibe (2021), businesses utilise such actions to fulfil the demands of clients to compete in the marketplace. In addition, as per Peter, Munga, and Nzili, (2021), it helps organisations to increase its productivity. Process innovation according to Azar and

Ciabuschi, (2017) allows the reengineering and upgrading of the capacities of a company. According to Koyluoglu and Dogan (2021), the adoption of strategic plans that will provide supporting action to implementation, development, and provision of process innovations is what is required for a firm to be relevant and competitive in the business environment.

It is necessary for firms to ensure that they remain in business in the cutthroat business environment, and to do this, firms need to be innovative. According to Ekeh, (2023), businesses should use process innovation to make their daily operations more efficient as well as in the production of products tailored to their target market. According to Drucker, (1985), one of the goals of process innovation is to attract new clients as well as retain the existing clients.

1.2 Statement of the problem

Over the years manufacturing firms have been struggling with poor performance in terms of firm's production capacity. Mangers of these firms have adopted various measures to improve productivity, how be it, all of these measures which are human based, yielded not much result.

According to Wambua and Stephen (2021), process innovation is the only way to improve firms operations and provide it a sustained competitive edge. They also highlighted that even if innovation does not have a significant effect on an organisation's business market directly, it can still help the firms generate dynamic capabilities that can be utilised to secure an early competitive advantage, especially during market changes. Despite this allusion, many of the manufacturing firms in Rivers State are still struggling with the issues of increase productivity. These problems arise because of the lack of will by firms in taking up new technology. The infrastructural challenges refer to the Government inability to provide adequate power supply for this technology to strive, resulting high cost of operations by manufacturing firms in the state, hence, their unwillingness to adopt process innovation that are technology driving.

However, there have been a plethora of research done on the subject of process innovations and how it impacts business performance. Various studies (Ekeh, 2023; Namusonge, Muturi & Olaniran, 2016; Nwankwo & Ezeibe, 2021) have emphasised that failure in process innovation leads to a huge loss in business operations of an organisation. These studies and many more as reviewed, have not been able to analyse process innovations with the dimensions adequate for firm's performance. Changes in the business environment have affected the way several manufacturing firms in Rivers State operate and the level of their performance.

Namusonge, Muturi and Olaniran, (2016), asserted that manufacturing companies need now to find means of providing customers with high quality goods that are cheaper to obtain and the only means of achieving this is through process innovation. They also stressed the necessity for manufacturing companies to look for ways to upgrade their current products and offer new ones in a more lucrative way if they are to remain competitive and retain their place in the market. This has meant that there is pressure on them to implement process innovation as a means of improving their performance.

It is impossible to overstate the importance of process innovation because it may be said to be tool for improving firm's performance and achieving firm competitive advantage. Therefore, the purpose of this study was to measure the dimensions of process innovation and the relationship of process innovation dimensions to the performance of manufacturing firm in Rivers State.

1.3 Aim and Objectives of the Study

The aim of this study is to investigate the relationship between process innovation and performance of manufacturing firms in Nigeria. Specifically, the study sought to:

i. establish the effect of Additive manufacturing (3D Printing) metrics on productivity of manufacturing firms in Rivers State.
ii. determine the effect of Lean-Six-Sigma performance dashboards on productivity of manufacturing firms in Rivers State
iii. determine the effect of AI-driven predictive maintenance metrics on productivity of manufacturing firms in Rivers State.

1.4 Hypotheses

H01: Additive manufacturing (3D Printing) metrics has no significant relationship with productivity of manufacturing firms in Rivers State

H02: Lean-Six-Sigma performance dashboards has no significant relationship with productivity of manufacturing firms in Rivers State

H03: AI-driven predictive maintenance metrics has no relationship with productivity of manufacturing firms in Rivers State?

2.0 Literature Review

2.1 Conceptual Framework

2.1.1 Process Innovation

Faith and Simon (2023) crafted a definition of process innovation which comprises "the process of improving the methods of production and logistics of an organisation in order to radically improve all of its supporting activities such as purchasing, accounting, computer, and maintenance". This definition was in line with that of Rogers (1962) who believed that process innovation entailed any major enhancements made to the entire process of production and delivery, regardless of the tools, technologies or software utilised. They also underlined the need for businesses to innovate their business practises in order to increase their productivity across the board. The term "process innovation" is usually talking about a complete novel approach that is not adopted or implemented by the company yet. The process may have been developed by the business itself or with the help of some external (Namusonge, Muturi & Olaniran, 2016). According to Alves, Galina and Dobelin (2018), "process innovation" denotes judgement changes in an organisation with the adoption of new information and communication technologies. This includes implementation of new path ways in practise or enhancing an existing technique to develop an entire process in an organisation.

Process innovation is an integrated approach that is used by a business to improve the overall process of production (Hari, Fredi & Eneng, 2020). According to Domnich (2022), process innovation is an organisational capability and is the combination of resources and manufacturing processes to create new processes or improve existing ones.

There are a number of dimensions of process innovation in the manufacturing firms. How be it, this paper looked at two dimensions and they include the following: Additive manufacturing (3D Printing) metrics and Lean - Six Sigy performance dashboards, Shilin L. and Hanlie Cheng (2024).

Additive manufacturing (3D Printing) Such metrics: This innovation is applied to determining the number of parts produced in an addictive manner, the lead-time reduction and material waste reduction. It measures the extent to which new technologies are transforming old procedures, Reichstein and Salter, (2006).

Lean-Six Sigma performance dashboards: This innovation is used to tracking product defect rates, cycle-time reduction, and waste percentages (e.g. SMED, Kanban) provide a quantifiable view on the effectiveness of continuous improvements, Damanpour and Aravind, (2012).

AI - Driven Predictive Maintenance Metrics: The innovation is an Algorithms of predicting the equipment failure, so that the frequency and accuracy of the maintenance interventions, becomes a measure of the impact of the innovation, Damanpour and Aravind, (2012).

2.1.2 Performance

Performance is a multifaceted concept that could be measured in many different ways, including, customer happiness, market share, brand reputation, number of workers, profitability and productivity. Additionally, with both financial and not financial goals considered when determining the performance of an organisation, organisational performance may be viewed from either perspective (Rajapathiria & Hui, 2018; Olulu-Briggs & Wobo, 2023; Olulu-Briggs, 2022). The efficiency and effectiveness of an organisation when it comes to production and accomplishment of goals can also be linked to the good standing of a firm. According to Nwankwas and Ezeibe, (2021), performance is the results that an organisation achieves with respect to its aims and objectives. Performance was defined by Mugane and Ondigo, (2016) in terms of growth, success, survival and competitiveness. According to Azar and Ciabuschi (2017), performance of an organisation is its ability to achieve its overall mission and vision due to its dedication, effective management and sound governance. According to El-Kassar and Singh (2019), performance is the way an organisation's profit, the quality of its products and market share compare with the previous year's performance of other similar businesses within the same industry. They went on to explain that performance is gauged in reference to a specific standard and when that standard is met, it is believed that the organisation performance has improved. Additionally, Peter, Munga and Nzili, (2021) stressed that the accomplishment of a goal is performance.

2.1.2.1 Productivity

Productivity is the efficiency and effectiveness of the work of an individual, team, organization, or system in regards to producing output or to achieving goals. It is often measured against the ratio of output to inputs, such as labour input, material input, or time input, OECD (2001).

2.2 Theoretical Framework

2.2.1 Diffusion of Innovation Theory

Everett Rogers dike up the Diffusion of innovation Theory in 1962. Rogers developed this idea as a means to demonstrate how new inventions and technology are being adopted and used by a particular social system or population. Diffusion, according to his book, is the process of sharing innovation by members of some system. In the opinion of Kindstrom and Kowalkowski, (2014), diffusion may be seen as the communication and sharing of knowledge amongst members of a certain system. This leads to the adoption of a certain new idea, process or product. According to Rogers (1962), corporations adopted this theory because they needed to get rid of misinformation, uncertainties and excessive costs while embracing innovations and innovative techniques to increase productivity.

In addition, according to Barrett, Davidson, Prabhu and Vargo (2015), the theory is founded on four basic concepts; Time, Social systems, communication and innovation. Time is believed to be one of the most important factors since it influences the pace at which and the depth of the adoption of innovations by a business. This is the case because different social systems have at different times and rates embraced innovations leading to the categorization of some as early adopters, early majorities and the rest as late majorities or laggards. Azar and Ciabuschi, (2017) claimed that an organisation's performance will depend on how much it embraces innovation. Innovation is spread in many different forms and in many various cultures as well as industries. These manifestations are usually dependent on the organisational decision-making process and also the types of adopters (Alves, Galina & Dobelin, 2018). Manufacturing companies come across radical since they often rely on innovation to effect the kind of adjustments they need to perform significantly better. This theory is relevant to extent as it explains how new inventions and technology can be adopted and used by the manufacturing firms to improve on its performance.

2.2.2 Resource based view (RBV) Theory

Penrose designed this theory to explain the role of an organisation's internal resources in the evolution of a sustained competitive advantage in the marketplace. According to Penrose (1959), some participants in an industry are perceived to perform better than others in the same industry on a consistent basis due to well-organised and valuable resources and this is a factor in the competitiveness of an organisation. Among other people, Peteraf & Bergen (2003) and Barney (1996) hold the same view as Penrose. RBV, as defined by Barney (1996) is variety in organisational ranks in the industry. According to the RBV, different individuals have suggested that it is reasonable for an entity to assert a competitive benefit if it is able to make successful and efficient use of its resources.

The resource-based theory believes that while an organisation is endowed with a variety of resources, not all are significant in helping the firm achieve its competitive advantage. It is expected that an organisation research its resources before designing any strategy (Eisenhardt & Martin, 2000). This is understandable because ultimately, an organisation's resources will determine the performance on the firm and sustainability regarding a strategy. This theory can be used in this study to help the manufacturing company understand the value of their resources and talents, especially when implementing an innovative strategy. It reveals that to boost the performance, this company must determine what their resources are and make the best use of them. This theory has implication on this study because it provides information of how the internal resources within the firm can influence the development of a long-lasting competitive edge within the market place.

2.3 Empirical Review

Tina (2025) examined the intersection between technology adoption and employee engagement using teaching staff at a private university for the study Using the Diffusion of Innovations Theory, it revealed the different factors affecting technological integration attitudes and behaviours. A cross-sectional survey was carried out, which included quantitative approach and secondary data analysis. The results showed that the majority of the research subjects (65.11%) were males, 34.88% were 56 years of age and over, 46.51% had Ph.D. degrees, and 81.39% were Yoruba people. Furthermore, 53.48% of the participants stated that the technologies that were implemented were aligned to their learning objectives, and 65.11% of the participants of the study felt that these technologies promoted the learning experience of students. Additionally, 46.51% reported an increase in job satisfaction due to the adoption of technology.

Augustine, et al. (2023). examined the applicability of process innovation as a strategic tool in combating organisational performance and strategic management in the case of manufacturing company in Nigeria. The study used descriptive survey research methodology and population of the study consisted 7.533 employees from specifically 3 chosen manufacturing companies in Nigeria: Lafarge Africa Plc, Flour Mill Nigeria PLC and PZ Cussons. The size of the sample to be used for the study was calculated using the Formula of Andrew Fisher to be 366 and the distributed questionnaire was set on a five point Likert scale. Out of the 366 questionnaires distributed, 340 were returned, giving the response rate of the study 93%. Data that were obtained were examined using the statistical software package, Statistical Package and System (SPSS). The result

of this research showed a large amount of correlation between the two variables and it was concluded that process innovation is significant to improve an organisational performance.

Loveday (2023). The process innovation effect on medium enterprise growth was investigated in North Central Nigeria. The population of the study was a sample of 243 medium sized enterprises in North Central Nigerian area. The study used the census approach to the entire population of 243 owner/managers of these medium enterprises in North-Central Nigeria were used as the sample size of the study. Questionnaires were therefore, administered on this sample but only 223 were usable for analysis. The result of regression showed that process innovation had significant positive effect on the growth of medium enterprises in North central State, Nigeria. The results of this study showed that process innovation practise had positive significant effects on growth of medium enterprises in North Central Nigeria.

Mohammed and Kamariah (2022) investigated the ability of exploring the impact of product and process innovations on firm sector, ownership type, size and activity performed. Demographic information regarding their perception regarding product and process innovation. Four demographic variables i.e., sector, type of ownership, size of company, and the main activity of the companies are selected as predictors while the relationships between these variables and two dependent variables product and process innovations and was studied. A total of eight hypotheses were formulated, relating each of the predictors to both dependent variables and individually: Based on the questionnaire designed, the questions were aimed at determining firms perceptions towards product and process innovations in their firms A survey was conducted on SMEs firm of different organisations. The simple random sampling technique was adopted with the sample size comprised of 1778 firms involved in the survey conducted in Malaysia. A simple random sampling was used to select the firms within the manufacturing and service sector from SMEcorps Malaysia data based and contacting established by survey all the selected firms. That data collected was processed through the software known as SPSS and analysed by using One-Sample T-test and ANOVA. It was seen that none of the predictors caused significant variation in SMEs firm perceptions with respect to the firm's responses on the demographic variables of the firm.

Nassr (2021) examined the effectiveness of electronic services and the digital transformation in the selected public sector in the Sultanate of Oman. The study used online empirical sources in the name of organisational, technology, environment and human resource factors, as well as in the effectiveness of digital change in various online database sources like: Google Scholars, Springer link, Wiley, Science Direct, JSTOR, Emerald full text, Scopus and Ebscos Host, etc The results presented in the review indicate that organisational, technological, environmental and human issues play an important role in ensuring the effectiveness of the public sector in the digital transformation process in the Sultanate of Oman. The researchers also found that the success of e-government in Oman depends on the willingness and intention of the citizens to take advantage of the e-government services.

Shathees et al, (2020) focused on the topic Adoption of technology and employees and Job performance: An empirical investigation. Technology innovation has an important influence on employee's job performance where it helps to reduce human error, increase productivity, and increase the speed of communication. Many organisations are facing difficulties in selecting appropriate technology adoption strategies with the hope to improve efficiency and enhance the performance of employees to be competitive in the market. Several dimension for employee job performance were considered in this research namely job stress, motivation, and workload. In addition, the mediating effect of perceived job insecurity was also tested on technology adoption and employee job performance relationship. Applying quantitative research method, data was gathered from 370 respondents using the structured online survey questionnaire method. Data was analysed with using Statistical Package for Social Sciences (SPSS) software. This is an IBM (SPSS) software that is used to summarise and analyse the data collected from the survey, in addition to exploring the relation between the answers provided to a different question. Besides, SPSS also well serve in calculating the correlation between the research variables and the mediators and transform the raw data into usable information which will address the research question and hypothesis. The results showed that job satisfaction and motivation were successful to be statistically significant but workload failed to be retrieved in the research. Additionally, in the research there was no statistical evidence of the mediating effect of job insecurity. It is envisaged that these findings will provide incremental insights into the existing body of knowledge while provide some directions to the organisation in determining the right set of drivers inculcating technology adoption for improved job performance.

Oginni, El-Maude, Mohammed and Michael (2016) examined relationship between e-payment system and economic growth as a means of reviewing the current transition to cashless economy in Nigeria. Data was analysed with the help of OLS and TSLS with 10 years period (2005-2014). The result indicates existence of simple positive relationship between e-payment system and economic growth in term of real GDP, per capita and trade per capita. Only ATMs was found to contribute positively to economic growth and other e payment channels contribute negatively. Hence, current cashless policy should be tailored towards effective e-payment system and other factors which bear much relevance on successful transition to cashless economy should be prioritised.

Vincent, Caroline and Kemboi (2016) analysed the effects of mobile banking on the financial performance of commercial banks in the Kapsabet Town. The research design adopted is descriptive where the selected banks in Kapsabet were studied. The study used stratified random sampling method as one of the techniques of probability method, which was carried out

based on the bank structure. Purposive sampling technique was adopted in selecting management team and head of departments while Simple Random Sampling technique was adopted in selecting bank staff and bank customers. Questionnaire and interview schedule have been used as the major instrument of data collection for this study. The reliability of the questionnaires used to test the study was measured using the Cronbach alpha to determine the internal consistency of the items. The data collected from the research instruments were analysed using Statistical Package for Social Science (SPSS) version 20. Descriptive and inferential statistics were adopted in analysing data. Descriptively frequencies and percentages were used to analyse demographic data where testing variables in hypothesis was inferential analysis using multiple regression model. The expectation of the study was that the financial performance of commercial banks improves through mobile banking. The findings of the study reveal that there was the significant relationship between mobile banking and financial performance ($p<0.005$). The study therefore concluded that mobile banking would make it easier to send money to receiver instantly.

3.0 Methodology

The research design is cross sectional Survey; with correlational inquiry type. Using this method a copy of questionnaire were used in collecting the data. According to Trochim (2006) survey research enables research to ascertain people's knowledge, preferences, and thoughts by means of utilising copies of questionnaire and interviews.

The term "population" is applied to the group of individuals, things, or traits from which a researcher intends to make statistical conclusions. Population is defined as the sum total of the people, groups, organisations, or entities of which the researcher intends to suppress research (Ahiauzu, 2010; Sunday & Etugbo, 2023). The population in this study are permanent workers of 28 registered manufacturing firms in Rivers State that consist of 850 employees in Rivers State according to the State directory of register. For the study, the formula that has been used to select the sample size was from Rose, Spinks, and Canhoto, (2015). Based on the formula for calculation of sample size, for the population of 850 permanent employees of 28 registered manufacturing firms in Rivers State, the sample size calculated was 120 which was selected using stratified random sampling technique from each subgroup. The sampling units has been selected from each of the strata in the manufacturing (agro, plastic, chemicals, machine and equipment, textile and furniture manufacturing) firms. The stratified random sampling technique was followed in order to ensure that the respondents were a representation of each of the subgroups of population of study. According to Adams et al, (2007), Stratified sampling is applied after population is grouped homogenously. Samples are then drawn proportional to each of the strata. In the study, the samples from each stratum have been chosen according to the proportion with the size of the population of the stratum. This gave a sampling size of 120.

Primary data was collected from the respondents by using the questionnaire as a tool. The results of the study were obtained from 120 copies of questionnaire administrated to the intended participants. The Like bipolar 5 point scale, which ranges from Very Strong Extent to Very Low Extent, was utilised to create the questionnaire.

In order to find out the dependability, The Cronbach's Alpha method was employed to analyse the questionnaire by using statistical package for social science (SPSS). The score of Cronbach alpha ranges from 0 to 1, the pilot test result which is said to be consistent and reliable is the case when the value of the coefficient of Cronbach alpha is said to be higher. For the value of 0.7 and above it shows the internal consistency reliability is satisfactory (DeVellis, 2016). If the a coefficient is less than or equal to 0.7, then it is considered low reliability and is not acceptable because it will affect the overall result to be inaccurate. Thus, the issue of reliability in this research is considered fully to suit the research needs and purpose best. A pilot study was carried out by giving the survey questionnaires to twenty respondents prior to the main research. This was a pilot test to cheque the viability of this approach before moving forward into a large scale study. Once, the pilot test result suits the purpose of the study, survey questionnaires will be distributed to a large scale of respondents.

Table 3.1: Instrument Reliability

Construct	*Cronbach's Alpha*
Additive manufacturing (3D printing) metrics	0.842
Lean-Six-Sigma performance dashboards	0.889
AI-driven predictive maintenance metrics	0.821
Productivity	0.718

Based on the test result from the pilot test, all four variables have a scale score for Cronbach's alpha which is higher than 0.7. According to DeVellis (2016), the a coefficients more than or equal to 0.7, acceptable, and can be brought forward to the next process of large-scale distribution throughout the manufacturing firms in Rivers State.

At the first level of analysis, the statistical measures of descriptive statistics such as mean, standard deviation, frequency table, and simple percentages were implemented in the data. At the secondary level, the hypotheses on the direction and degree of relationships between process innovation in Rivers State and performance of manufacturing firms were tested using bivariate inferential statistic of Pearson's Product Moment Correlation. Statistical Package for the Social Sciences (SPSS) version 23.0 was utilised to run all the statistical analyses.

4.0 Result and Discussion

4.1 Data Presentation

This section of the study involved the analysis of the study instrument in terms of the number of instruments produced, distributed, retrieval and used by the researcher. Frequency distribution and percentages were used to analyze the instrument as shown in Table 1 below.

Table 1: Questionnaire Administration and Use

Questionnaire	Frequency	Percent
Produced Copies	120	100
Distributed Copies	120	100
Retrieved Copies	113	95.76
Copies not Retrieved	7	4.23
Valid Copies	108	90.68
Invalid Copies	5	5.08

Source: Field Survey, 2025.

A total of 120 copies (100%) of the questionnaire were created and given to the intended respondents, as can be seen from the data in Table 2 on the questionnaire's creation, administration, and use. 113 copies (95.76%) of the 120 copies that were distributed were recovered, while 7 copies (4.23%) were not returned. Furthermore, only 108 copies (90.68%) of the 113 copies that were obtained were used for the analysis because 5 copies (5.08%) were deemed invalid.

Table 2: Descriptive Statistics of Additive manufacturing (3D Printing) metrics

Descriptive Statistics

	N	Sum	Mean	Std. Deviation	Variance
Our firm uses Additive manufacturing (3D Printing) metrics for productions	108	414	3.87	1.133	1.285
The use of additive manufacturing metrics scaled our production	108	444	4.15	1.139	1.298
Our staff are well trained on additive manufacturing (3D Printing) metrics	108	435	4.07	.587	.345
Our employee adoption of additive manufacturing (3D Printing) metrics is high	108	439	4.10	.700	.489
Valid N (listwise)	108				

Source: SPSS Output, 2025.

Table 2 depicts high mean scores of the questionnaire items ranging over 3.00, this means that greater number of the respondents expressed very high and high extents of acceptance to the research question with respect to Additive manufacturing (3D Printing) metrics. However, it can be seen that question 2 which sought to determine the extent to which manufacturing firms in Rivers State use additive manufacturing metrics to scale production, has the highest mean score of 4.15. This shows that question 2 has the strongest influence on the variables.

Table 3: Descriptive Statistics of Lean-Six-Sigma performance dashboards

Descriptive Statistics

	N	Sum	Mean	Std. Deviation	Variance
Our firm uses Lean-Six-Sigma performance dashboards for productions	108	439	4.10	.628	.395
The use of Lean-Six-Sigma performance dashboards scaled our production	108	434	4.06	1.220	1.487
Our staff are well trained on Lean-Six-Sigma performance dashboards	108	438	4.09	.524	.274
Our employee adoption of Lean-Six-Sigma performance dashboards is high	108	446	4.17	.693	.481
Valid N (listwise)	108				

Source: SPSS Output, 2025.

Table 3 depicts high mean scores of the questionnaire items ranging over 3.00, this means that greater number of the respondents expressed very high and high extents of acceptance to the research question with respect to Lean-Six-Sigma performance dashboards. However, it can be seen that question 4 which sought to determine the extent to which the employee's of manufacturing firms in Rivers State have been adopted Lean-Six-Sigma performance dashboards to increase productivity, has the highest mean score of 4.17. This shows that question 4 has the strongest influence on the variables.

Table 4: Descriptive Statistics of AI-driven predictive maintenance metrics

Descriptive Statistics

	N	Sum	Mean	Std. Deviation	Variance
To what extent do your organization use AI-driven predictive maintenance metrics?	108	438	4.09	.524	.274
To what extent does your organization regularly audit suppliers for compliance with environmental standards and pollution control measures?	108	451	4.21	.701	.491
To what extent does your organization assess energy efficiency and waste reduction mechanisms adopted by suppliers?	108	416	3.89	1.102	1.214
To what extent does your organization use overall commitment to sustainability as metrics to evaluate supplier performance?	108	411	3.84	1.117	1.248
Valid N (listwise)	108				

Source: SPSS Output, 2025.

Table 5 depicts high mean scores of the questionnaire items ranging over 3.00, this means that greater number of the respondents expressed very high and high extents of acceptance to the research question with respect to green supplier evaluation. However, it can be seen that question 2 which sought to determine the extent to which general hospitals in Rivers State regularly audit suppliers for compliance with environmental standards and pollution control measures, has the highest mean score of 4.21. This shows that question 2 has the strongest influence on the variables.

Table 5: Descriptive Statistics of Productivity

Descriptive Statistics

	N	Sum	Mean	Std. Deviation	Variance
Our firm surpasses her production target	108	451	4.21	.701	.491
Our product are of high quality standard	108	441	4.12	1.070	1.145
Our market share is on the increase	108	418	3.91	1.069	1.142
We are satisfied with our productive capacity	108	403	3.77	1.202	1.445
Valid N (listwise)	108				

Source: SPSS Output, 2025.

Table 5 depicts high mean scores of the questionnaire items ranging over 3.00, this means that greater number of the respondents expressed very high and high extents of acceptance to the research question with respect to Productivity. However, it can be seen that question 1 which sought to determine the extent to which manufacturing firms in Rivers State have been able to meet and surpass production target in competitive environment, has the highest mean score of 4.21. This shows that question 1 has the strongest influence on the variable

Test of Hypotheses

$H0_1$: Additive manufacturing (3D Printing) metrics has no significant relationship with productjty of manufacturing firms in Rivers State.

Table 6: Correlations of Additive manufacturing (3D Printing) metrics and productivity

Correlations

		Additive manufacturing (3D Printing) metrics	Productivity
Additive manufacturing (3D Printing) metrics	Pearson Correlation	1	.540**
	Sig. (2-tailed)		.000
	N	108	108
Productivity	Pearson Correlation	.540**	1
	Sig. (2-tailed)	.000	
	N	108	108

**. Correlation is significant at the 0.01 level (2-tailed).

Source: SPSS Output, 2025.

Table 7 of the SPSS report shows that there is a very favorable relationship between Additive manufacturing (3D Printing) metrics and Productivity, with a correlation coefficient of 0.540**. In addition, the critical value is 0.05, and the probability value is 0.000, indicating a highly significant relationship between Additive manufacturing (3D Printing) metrics and Productivity. What this means is that manufacturing firms in Rivers State can leverage on Additive manufacturing (3D Printing) metrics to increase productivity. Accordingly, we accept the alternative hypothesis, which states that manufacturing firms in Rivers State engage in Additive manufacturing (3D Printing) metrics to increase productivity, and reject the null hypothesis, which states that no such relationship exists.

$H0_2$: Lean-Six-Sigma performance dashboards has no significant relationship with productivity of manufacturing firms in Rivers State

Table 7: Correlations of Lean-Six-Sigma performance dashboards and productivity

Correlations

		Lean-Six-Sigma performance dashboards	Productivity
Lean-Six-Sigma performance dashboards	Pearson Correlation	1	.769**
	Sig. (2-tailed)		.000
	N	107	107
Productivity	Pearson Correlation	.769**	1
	Sig. (2-tailed)	.000	
	N	108	108

**. Correlation is significant at the 0.01 level (2-tailed).

Source: SPSS Output, 2025.

The SPSS output on Table 8 reveals a correlation coefficient of 0.769** between Lean-Six-Sigma performance dashboards and productivity, indicating a strong positive relationship between Lean-Six-Sigma performance dashboards and productivity. More so, the probability value (0.000) is less than the critical value (0.05), this shows that there is a strong significant relationship between Lean-Six-Sigma performance dashboards and productivity. This further implies that Lean-Six-Sigma performance dashboards can be used to achieve increase productivity among manufacturing firms in Rivers State. Based on this, we reject the null hypothesis that there is no significant relationship between Lean-Six-Sigma performance dashboards and productivity of manufacturing firms in Rivers State and accept the alternate hypothesis that there is a strong, significant relationship between Lean-Six-Sigma performance dashboards and productivity of manufacturing firms in Rivers State.

$H0_3$: AI-driven predictive maintenance metrics has no relationship with productivity of manufacturing firms in Rivers State

Table 8: AI-driven predictive maintenance metrics and productivity

Correlations

		Green Supplier Evaluation	Cost Minimization
Green Supplier Evaluation	Pearson Correlation	1	.766**
	Sig. (2-tailed)		.000
	N	108	108
Cost Minimization	Pearson Correlation	.766**	1
	Sig. (2-tailed)	.000	
	N	108	108

**. Correlation is significant at the 0.01 level (2-tailed).

Source: SPSS Output, 2025.

Table 9 of the SPSS report shows that there is a very favorable relationship between AI-driven predictive maintenance metrics and productivity, with a correlation coefficient of 0.766**. In addition, the critical value is 0.05, and the probability value is 0.000, indicating a highly significant relationship between AI-driven predictive maintenance metrics and productivity. What this means is that manufacturing firms in Rivers State can leverage AI-driven predictive maintenance metrics to increase productivity. Accordingly, we accept the alternative hypothesis, which states that manufacturing firms in Rivers State engage AI-driven predictive maintenance metrics to increase productivity, and reject the null hypothesis, which states that no such relationship exists.

4.2 Discussion of Findings

From the table (SPSS report 7), there is also a very good relationship between Additive manufacturing (3D Printing) metrics with Productivity, we can observe the correlation coefficient that positively, which is 0.540**. In addition, the critical value is 0.05 and the probability value is 0.000, which means that the relationship between Additive manufacturing (3D Printing) metrics and Productivity is very significant. This result suggests that manufacturing firms in Rivers State leverage on Additive manufactures (3D Printing) metrics to increase productivity. Accordingly, alternative hypothesis was accepted, This assertion was validated from findings in work of Augustine et al (2023) as they studied the possibilities of process innovation as a strategic tool that could be used to enhance organisational performance using manufacturing companies in Nigeria, and found that there was a significant correlation between both variables.

Again, The SPSS output on the table 8 shows correlation coefficient of 0.769** between the Lean Six-Sigma performance dashboards and productivity, which shows that there is a strong relationship between Lean-Six-Sigma performance dashboards and Productivity. More over, the probability value (0.000) is less than the critical value (0.05), the implication is that Lean-Six-Sigma performance dashboards can be used to achieve increase productivity among manufacturing firms in Rivers State. These views were substantiated by the findings in the works of Loveday (2023) who investigated the effect of process innovation on growth of medium enterprises in North Central Nigeria, which results revealed that process innovation had significant positive effect on the growth of medium enterprises in North-Central Nigeria.

Also, the correlation coefficient among AI-driven predictive maintenance, productivity is 0.766**. In addition, the critical value is 0.05 and the probability value is 0.000 which means there is a highly significant relationship between AI-driven predictive maintenance metrics and productivity. What this entails is that, AI-driven predictive maintenance metrics could be used to achieve manufacturing firm's objective of increase productivity. This allusion is in consonance with the findings in the works of Loveday, (2023), as he investigated the effect of process innovation on growth of medium enterprises in North Central Nigeria

5.0 Conclusion and Recommendations

In-view of our discussion of findings, namely, that manufacturing firms in Rivers State engage in process innovation to increase productivity. We conclude that there is a high significant relationship between Additive manufacturing (3D Printing) metrics, Lean-Six-Sigma performance dashboards, Artificial Intelligence (AI) - driven predictive maintenance metrics and to increase productivity of manufacturing firms in Rivers State. We submit that there exists a positive and significant relationship between process innovation and manufacturing firms performance in Rivera State.

It is recommended as follows from the study:

i. Managers of manufacturing firms in Rivers State should further increase the adoption of Additive manufacturing (3D Printing) Metrics, in order to enhance productivity.

ii. Organisational/Management Desk The Management of manufacturing firms in Rivers State should regularly organise regular training for their employees on the use of Lean-Six-Sigma performance dashboards, as a means of in-view of tracking product defect rate, cycle-time reduction, and waste percentages.

iii. Manufacturing firms in Rivers State should apply forecasting tool known as Predictive Maintenance Metrics for efficient and unhindered manufacturing process.

The limitations of the study are as follow:

i. This research is limited in its content as it discussed only process innovation dimensions and performance index that are manufacturing industry specific.

ii. It is also limited in geographical size, the manufacturing firms studied are located within the raider of Rivers State.

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