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TOTAL PRODUCTIVE MAINTENANCE (TPM) IMPLEMENTATION AND OVERALL EQUIPMENT EFFECTIVENESS (OEE) IN MANUFACTURING FIRMS IN RIVERS STATE

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ABSTRACT

This study examines the relationship between Total Productive Maintenance (TPM) Implementation and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state. This study was operationalized by Productive Maintenance (TPM) Implementation as the predictor variable with dimensions of autonomous maintenance, planned maintenance, quality maintenance and the criterion variable was Overall Equipment Effectiveness (OEE) with measures of availability, performance and quality. Cross sectional survey design was adopted for this study. The population of this study is thirty two (32) manufacturing companies in Rivers State which are registered with the Rivers branch of Manufacturers Association of Nigeria (MAN). The sample size for this study is the thirty two (32) manufacturing companies earlier indicated as the population. The study adopted the census techniques. Three key managers (production manager, marketing manager and logistics manager) were chosen as respondents from each, of the thirty two firms is the sample. This gave us a total of ninety two (92) for the study. Structured questionnaire was adopted for the study. The result of the Cronbach's Alpha reliability test indicate .806 which is above .70 which implies that the items are reliable. The research questions were analysis with the aid of descriptive statistics using mean and standard deviation while hypotheses were tested using Pearson product moment correlation on SPSS. The study revealed that there is a significant relationship between Autonomous Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state. There is a significant relationship between Planned Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state. There is a significant relationship between Quality Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state. The study concluded that there is a positive relationship between Total Productive Maintenance (TPM) Implementation and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state. The study recommended among others that Manufacturing firms should develop a comprehensive TPM implementation plan tailored to the specific needs and challenges of manufacturing firms in Rivers state.

INTRODUCTION

Background to the Study

Overall Equipment Effectiveness (OEE) is a key performance indicator used in the manufacturing industry to measure the efficiency of production processes. It provides a comprehensive view of how well equipment is utilized by taking into account three main factors: availability, performance, and quality. Availability refers to the percentage of time that equipment is available for production. This factor considers downtime due to maintenance, breakdowns, changeovers, and other factors that may prevent the equipment from running at full capacity. Performance measures the speed at which equipment operates compared to its maximum potential. It takes into account factors such as slow cycles, minor stops, and idling time that can reduce overall productivity (Smith, 2010).

Brown, (2017) Quality evaluates the number of good units produced compared to the total number of units produced. It considers defects, rework, and scrap that can impact the overall output quality. The study on Overall Equipment Effectiveness (OEE) aims to optimize these three factors to improve overall productivity and efficiency in manufacturing processes. By analyzing OEE data, companies can identify areas for improvement, implement strategies to increase efficiency, reduce waste, and enhance product quality. Overall, OEE provides a holistic approach to

measuring equipment performance and helps organizations make informed decisions to drive continuous improvement in their operations (Johnson, 2015).
Liker, et al., (2006) Total Productive Maintenance (TPM) is a comprehensive approach to equipment maintenance that aims to maximize the effectiveness of production machinery. TPM focuses on proactive and preventive maintenance strategies to minimize downtime, improve overall equipment efficiency, and enhance product quality. The implementation of TPM involves several key pillars, including Autonomous Maintenance, Planned Maintenance, and Quality Maintenance. Autonomous Maintenance; This pillar of TPM emphasizes empowering operators to take ownership of routine maintenance tasks on their equipment. By involving frontline employees in the care and upkeep of machinery, organizations can increase equipment reliability, reduce breakdowns, and foster a culture of continuous improvement.
Gijo, et al., (2010) Planned Maintenance in TPM involves scheduling regular maintenance activities based on equipment performance data and predictive analytics. By conducting maintenance proactively rather than reactively, organizations can avoid costly unplanned downtime and extend the lifespan of their assets. Quality Maintenance focuses on integrating quality control practices into the maintenance process to ensure that equipment operates within specified parameters and produces high-quality products consistently. By addressing quality issues at the source, organizations can prevent defects and rework, leading to improved product quality and customer satisfaction. Implementing Total Productive Maintenance requires a holistic approach that involves all levels of an organization, from frontline operators to senior management. By fostering a culture of collaboration, continuous improvement, and shared responsibility for equipment reliability and performance, organizations can realize significant benefits in terms of productivity, efficiency, and profitability.
There is a gap in the study of TPM implementation and OEE in manufacturing firms in Rivers state, Nigeria. While TPM and OEE are widely recognized as essential tools for improving operational efficiency and productivity in manufacturing settings, there is limited research specifically focusing on their implementation and impact in Rivers state(Lee, 2018, White, 2020).. Understanding how TPM practices influence OEE outcomes in manufacturing firms in Rivers state can provide valuable insights for enhancing operational performance and competitiveness in the region. It is in this regards that this study is carried out to determine the relationship between Total Productive Maintenance (TPM) Implementation and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.

Statement of problem
Overall Equipment Effectiveness (OEE) is a crucial metric used in manufacturing firms to measure the efficiency of production processes. White (2020) several problems can affect OEE in manufacturing firms. Some of the key issues include Downtime; Unplanned downtime due' to equipment breakdowns, maintenance issues, or lack of spare parts can significantly reduce OEE in manufacturing firms in Rivers State. It is essential for companies to implement preventive maintenance schedules and have spare parts readily available to minimize downtime. Quality Defects: Poor quality products can lead to rework, scrap, and decreased OEE. Quality control measures should be implemented to ensure that products meet specifications and standards consistently. Low Productivity: Inefficient production processes, inadequate training of, and lack of motivation among employees can result in low productivity levels, impacting OEE negatively. Companies should invest in employee training and motivation programs to improve productivity.
Supply Chain Issues: Delays in the supply chain, such as late deliveries of raw materials or components, can disrupt production schedules and lead to decreased OEE. Establishing strong relationships with suppliers and implementing effective inventory management practices can help mitigate supply chain issues. Lack of Data Analysis: Without proper data collection and analysis, manufacturing firms may not have insights into factors affecting OEE. Implementing real-time

monitoring systems and utilizing data analytics tools can help identify areas for improvement and optimize OEE performance. Overall, addressing these problems effectively can help manufacturing firms in Rivers State improve their Overall Equipment Effectiveness and enhance their competitiveness in the industry.

Total Productive Maintenance (TPM) is a proactive approach aimed at maximizing the efficiency and effectiveness of equipment through employee involvement, preventive maintenance, and continuous improvement initiatives. Implementing TPM can help reduce the problems affecting OEE in manufacturing firms in Rivers State by: Improving Equipment Reliability: TPM focuses on proactive maintenance strategies to enhance equipment reliability and reduce unplanned downtime, thereby increasing overall equipment availability. Enhancing Operator Skills: TPM emphasizes training and empowering operators to perform routine maintenance tasks and identify early signs of equipment issues, leading to improved performance rates. Optimizing Production Processes: TPM encourages streamlining production processes, reducing changeover times, and eliminating waste to enhance equipment utilization and performance (Gijo, et al., 2010).

It is observed that various empirical studies have been carried out on Total Productive Maintenance (TPM) Implementation and Overall Equipment Effectiveness (OEE)(Lee 2018; Smith, 2019). , however, there are still scare literature or rare studies are scare studies on Total Productive Maintenance (TPM) Implementation and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state, it is in the light of the above that this study seek to fill this lacuna by providing empirical evidence on the relationship between Total Productive Maintenance (TPM) Implementation and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.

Conceptual Framework

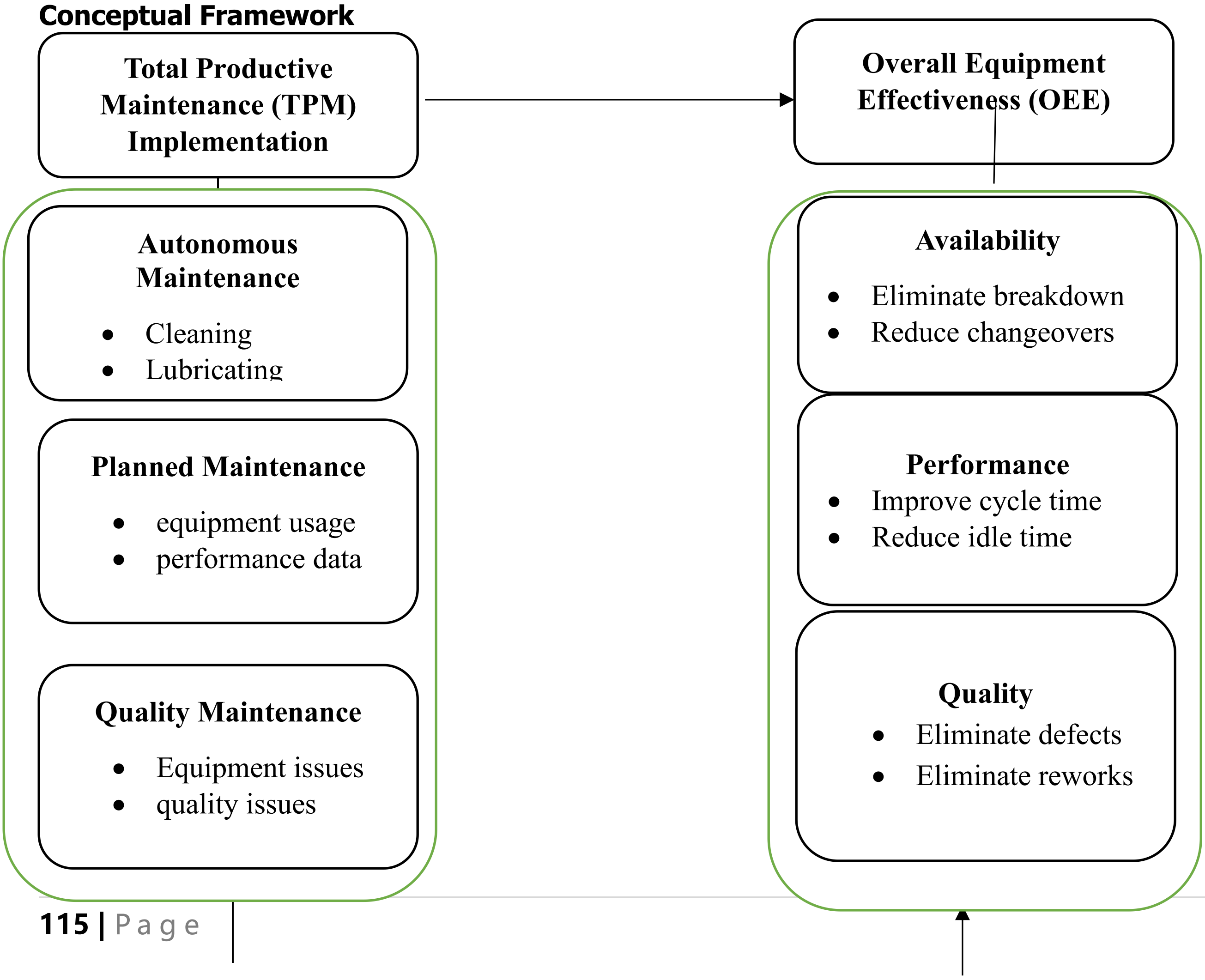


Figure 1: conceptual framework showing the relationship between Total Productive Maintenance (TPM) Implementation and Overall Equipment Effectiveness (OEE).
Source: Nakajima, (1988), Liker, Meier, & Morgan, (2006), Smith, (2010)

Aim & objectives
The aim of this study is to determine the relationship between Total Productive Maintenance (TPM) Implementation and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.
The study specifically sought to:

1) Determine the relationship between Autonomous Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.
2) Determine the relationship between Planned Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.
3) Determine the relationship between Quality Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.

Research Questions
The following research questions were raised to guide the study

1) What is the relationship between Autonomous Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state?
2) What is the relationship between Planned Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state?
3) What is the relationship between Quality Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state?

Research Hypotheses
The following null hypotheses were famulated and tested at a significance level of 0.05.

Ho_1: There is no significant relationship between Autonomous Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.

Ho_2: There is no significant relationship between Planned Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.

Ho_3: There is no significant relationship between Quality Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.

Significance of the Study
Total Productive Maintenance (TPM) is a comprehensive maintenance program that aims to maximize the effectiveness of equipment in manufacturing firms by involving all employees from top management to operators. Overall Equipment Effectiveness (OEE) is a key performance indicator used to measure the efficiency of equipment in a manufacturing setting. The study on TPM implementation and OEE in manufacturing firms in Rivers state holds significant importance as it can provide valuable insights into improving operational efficiency, reducing downtime, and increasing productivity in the manufacturing sector.
The significance of this study lies in its potential to enhance the overall competitiveness of manufacturing firms in Rivers state by optimizing their maintenance practices and equipment performance. By implementing TPM principles and monitoring OEE metrics, companies can identify areas for improvement, implement preventive maintenance strategies, and enhance overall equipment reliability. This can lead to cost savings, increased production capacity, improved product quality, and ultimately higher customer satisfaction.

The categories of persons that will benefit from this study include Manufacturing Managers: They can gain insights into best practices for implementing TPM and improving OEE to optimize production processes. Maintenance Engineers: They can learn about effective maintenance strategies to minimize downtime and enhance equipment reliability. Production Supervisors: They can understand how TPM practices can improve overall equipment performance and productivity on the shop floor. Quality Control Personnel: They can benefit from improved product quality resulting from enhanced equipment effectiveness through TPM implementation. Researchers and Academicians: They can use the findings of this study to further explore the relationship between TPM implementation, OEE, and operational excellence in manufacturing firms.

Scope of the Study

The scope of this study is categories into content scope, geographical scope and unit of analysis. The content scope of this study is centered on Total Productive Maintenance (TPM) Implementation with dimensions of Autonomous Maintenance, Planned Maintenance, Quality Maintenance and Overall Equipment Effectiveness (OEE) have measures of availability, performance and quality. Geographical scope of this study is manufacturing firms in Rivers state. The unit of analysis is Macro level which implies that managerial staff will constitute the respondents under study.

Conceptual Review

Total Productive Maintenance (TPM)

Total Productive Maintenance (TPM) is a comprehensive approach to equipment maintenance that aims to maximize the operational efficiency of machinery and minimize downtime. TPM focuses on proactive maintenance strategies, employee involvement, and continuous improvement to achieve optimal equipment performance. The implementation of TPM involves various key elements and practices that are essential for its successful execution. One of the fundamental principles of TPM is autonomous maintenance, which involves empowering operators to take ownership of routine maintenance tasks such as cleaning, inspection, and lubrication. By involving frontline employees in the upkeep of equipment, organizations can prevent breakdowns and improve overall equipment effectiveness. Additionally, TPM emphasizes planned maintenance activities such as preventive maintenance and predictive maintenance to address potential issues before they escalate into major problems (Liker, et al.,, 2006).

Total Productive Maintenance (TPM) is a comprehensive approach to equipment maintenance that aims to maximize the effectiveness of production machinery and minimize downtime. TPM originated in Japan in the 1960s as part of the Toyota Production System and has since been adopted by many manufacturing companies worldwide. The core principle of TPM is to involve all employees in the maintenance process and empower them to take ownership of equipment reliability. TPM focuses on proactive maintenance strategies to prevent breakdowns and defects, rather than reactive maintenance that only addresses issues after they occur. The goal of TPM is to achieve zero breakdowns, zero defects, and zero accidents by creating a culture of continuous improvement and employee engagement. Key elements of TPM include autonomous maintenance, planned maintenance, quality maintenance, focused improvement, early equipment management, and training and education (Liker, et al.,2006).

Autonomous maintenance involves operators taking responsibility for routine cleaning, inspection, and minor repairs of equipment to prevent deterioration and identify potential issues early. Planned maintenance involves scheduling regular inspections and servicing based on equipment condition monitoring data to prevent unexpected breakdowns. Quality maintenance focuses on eliminating defects at the source through root cause analysis and corrective actions. Focused improvement encourages employees to identify and implement small-scale improvements to enhance equipment performance. Early equipment management involves designing reliability into new equipment through collaboration between design engineers and maintenance personnel. Training and education ensure that all employees have the skills and knowledge necessary to support TPM initiatives(Smith, 2019).

By implementing TPM principles, organizations can improve overall equipment effectiveness (OEE), reduce downtime, increase productivity, enhance product quality, and create a safer work environment. TPM requires strong leadership commitment, employee involvement, cross-functional collaboration, continuous training, data-driven decision-making, and a culture of continuous improvement. Overall, Total Productive Maintenance is a holistic approach to equipment maintenance that goes beyond traditional preventive maintenance practices by involving all employees in the process of maximizing equipment effectiveness and minimizing downtime (Smith, 2019).

Gijo, et al.,. (2010) another critical aspect of TPM implementation is focused improvement activities, which involve identifying and eliminating sources of equipment inefficiency and waste. By conducting root cause analysis and implementing corrective actions, organizations can enhance equipment reliability and performance. TPM also promotes the use of cross-functional teams to drive continuous improvement initiatives and foster a culture of collaboration and problem-solving. Furthermore, TPM emphasizes education and training programs to equip employees with the necessary skills and knowledge to effectively implement TPM practices. Training sessions on equipment operation, maintenance procedures, and problem-solving techniques are essential for building a competent workforce capable of sustaining TPM initiatives in the long run. Moreover, establishing clear performance metrics and KPIs is crucial for monitoring progress, identifying areas for improvement, and driving organizational alignment towards TPM goals. Overall, the successful implementation of Total Productive Maintenance requires a holistic approach that integrates people, processes, and technology to optimize equipment performance, reduce costs, and enhance overall operational efficiency (Smith, 2019).

Dimensions of Total Productive Maintenance (TPM)

Autonomous Maintenance

Autonomous Maintenance is a crucial dimension of Total Productive Maintenance (TPM), which is a comprehensive approach to equipment maintenance that aims to maximize the operational efficiency of machinery in manufacturing environments. Autonomous Maintenance involves empowering operators and frontline workers to take ownership of routine maintenance tasks on their equipment. By involving operators in the maintenance process, TPM seeks to prevent equipment breakdowns, reduce unplanned downtime, and improve overall equipment effectiveness (Gijo, & Jiju 2005).

In the context of TPM, Autonomous Maintenance focuses on two primary objectives: restoring and maintaining equipment in optimal condition and preventing equipment deterioration through proactive measures. Operators are trained to conduct routine checks, inspections, cleaning, lubrication, and minor repairs on their assigned equipment. This proactive approach helps identify potential issues before they escalate into major problems that could disrupt production schedules. Furthermore, Autonomous Maintenance promotes a culture of continuous improvement by encouraging operators to develop a deeper understanding of their equipment and its maintenance requirements. By involving frontline workers in the maintenance process, organizations can leverage their knowledge and expertise to implement innovative solutions that enhance equipment reliability and performance (Gijo, & Jiju 2005).

Planned Maintenance

Planned Maintenance is a crucial dimension of Total Productive Maintenance (TPM), which is a comprehensive approach to equipment maintenance that aims to maximize the operational efficiency and effectiveness of machinery in an organization. TPM focuses on empowering employees at all levels to take ownership of equipment maintenance, with the goal of achieving zero breakdowns, zero defects, and zero accidents. Planned Maintenance, also known as scheduled maintenance or preventive maintenance, is a proactive strategy that involves regularly scheduled inspections, servicing, and repairs to prevent unexpected breakdowns and prolong the lifespan of equipment (Gijo & Jiju Antony 2005).

In the context of TPM, Planned Maintenance plays a key role in ensuring the overall equipment effectiveness (OEE) of machinery. By conducting routine maintenance tasks according to a predetermined schedule based on equipment usage and manufacturer recommendations, organizations can minimize unplanned downtime, improve productivity, and reduce maintenance costs. Planned Maintenance activities typically include tasks such as lubrication, cleaning, calibration, parts replacement, and inspection of critical components. One of the primary objectives of Planned Maintenance within the TPM framework is to shift from reactive maintenance practices (fixing equipment only when it breaks down) to proactive maintenance strategies that focus on preventing failures before they occur. By implementing Planned Maintenance schedules based on historical data, predictive analytics, and equipment performance metrics, organizations can identify potential issues early on and address them proactively to avoid costly downtime (Liker, et al., 2006).

Furthermore, Planned Maintenance fosters a culture of continuous improvement within an organization by encouraging collaboration between production operators and maintenance personnel. Through regular equipment inspections and maintenance checks, operators can provide valuable feedback on equipment performance and identify areas for improvement. This collaborative approach helps optimize equipment reliability and performance while enhancing overall operational efficiency. Overall, Planned Maintenance as a dimension of Total Productive Maintenance is essential for optimizing asset utilization, reducing downtime, improving product quality, and ultimately driving sustainable business growth through efficient equipment management practices(Gijo & Jiju Antony 2005).

Quality Maintenance

Quality maintenance is a crucial dimension of Total Productive Maintenance (TPM), which is a comprehensive approach to equipment maintenance that aims to maximize the productivity and efficiency of manufacturing processes. Quality maintenance within TPM focuses on ensuring that equipment operates at optimal levels to produce high-quality products consistently. By integrating quality maintenance practices into TPM, organizations can improve product quality, reduce defects, increase customer satisfaction, and enhance overall operational performance (Gijo, et al.,2010).

Gijo, and Jiju.(2005) One of the key principles of quality maintenance in TPM is the proactive identification and elimination of potential sources of defects or errors in the production process. This involves conducting regular inspections, implementing preventive maintenance measures, and addressing any issues that may affect product quality before they escalate into larger problems. By taking a proactive approach to quality maintenance, organizations can minimize downtime, reduce waste, and improve overall equipment effectiveness. Another important aspect of quality maintenance in TPM is the emphasis on employee involvement and empowerment. Employees are encouraged to take ownership of the quality of their work and participate in continuous improvement initiatives aimed at enhancing product quality. By involving employees in quality maintenance activities, organizations can tap into their knowledge and expertise to identify opportunities for improvement and implement effective solutions.

Furthermore, quality maintenance in TPM emphasizes the use of data-driven decision-making processes to monitor and evaluate equipment performance and product quality. By collecting and analyzing relevant data metrics, organizations can identify trends, patterns, and areas for improvement to optimize equipment reliability and product quality. This data-driven approach enables organizations to make informed decisions about resource allocation, process optimization, and performance enhancement. Overall, integrating quality maintenance as a dimension of TPM can help organizations achieve sustainable improvements in product quality, operational efficiency, and customer satisfaction. By focusing on proactive defect prevention, employee involvement, and data-driven decision-making processes, organizations can create a culture of continuous improvement that drives long-term success in today's competitive manufacturing environment (Gijo, et al.,2010).

Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE) is a key performance indicator used in manufacturing industries to measure the efficiency of production processes. It provides a comprehensive view of how well equipment is utilized in terms of availability, performance, and quality. OEE is calculated by multiplying three factors: availability (the percentage of time the equipment is running), performance (the speed at which the equipment operates compared to its maximum capacity), and quality (the rate at which the equipment produces good-quality products). The formula for OEE is: Each component of OEE provides valuable insights into different aspects of equipment performance. Availability measures the downtime of equipment due to breakdowns, changeovers, or maintenance. Performance assesses how efficiently the equipment is running compared to its ideal speed. Quality evaluates the number of good-quality products produced by the equipment (Smith, 2007).

By calculating OEE, companies can identify areas for improvement and optimize their production processes. A high OEE score indicates that the equipment is operating efficiently and producing high-quality products with minimal downtime. On the other hand, a low OEE score suggests that there are inefficiencies in the production process that need to be addressed. Improving OEE requires a systematic approach that involves analyzing data, identifying root causes of inefficiencies, implementing corrective actions, and monitoring progress over time. By focusing on improving availability, performance, and quality, companies can enhance their overall equipment effectiveness and achieve higher levels of productivity and profitability. In conclusion, Overall Equipment Effectiveness (OEE) is a powerful metric that helps manufacturing industries measure and improve the efficiency of their production processes. By monitoring and optimizing availability, performance, and quality, companies can enhance their operational excellence and drive continuous improvement in their manufacturing operations(Smith, 2019).

Overall Equipment Effectiveness (OEE) is a crucial metric used in the manufacturing industry to measure the efficiency and performance of equipment or processes. OEE is calculated by multiplying three key factors: Availability, Performance, and Quality. Availability is the first factor considered in OEE calculation. It measures the actual production time compared to the planned production time. Availability takes into account factors such as equipment breakdowns, changeovers, and scheduled maintenance. An Availability score of 100% indicates that the process is always running during Planned Production Time (Smith, 2007).

Performance, the second factor, assesses how well equipment is performing compared to its maximum potential. It considers aspects like equipment speed, minor stops, and idling time. A Performance score of 100% means that when the process is running, it operates at its maximum speed. Quality, the third factor in OEE calculation, evaluates the rate of production of "good count" products without defects or rework. Quality considers factors such as scrap, reject rates, and rework. A Quality score of 100% implies that only good parts are being produced without any defects (Gijo & Jiju 2005).

Measures of Overall Equipment Effectiveness (OEE)
Availability

Availability is one of the key components used to measure Overall Equipment Effectiveness (OEE) in manufacturing industries. OEE is a metric that quantifies how well a manufacturing process is performing by taking into account three factors: availability, performance, and quality. Availability specifically measures the percentage of time that a piece of equipment is available for production when it is scheduled to run. In the context of OEE, availability is calculated by dividing the actual production time by the planned production time. Planned production time includes all scheduled production hours minus any planned downtime, such as maintenance or changeovers. Actual production time is the total time the equipment was actually producing goods. The resulting percentage represents how effectively the equipment was available for production during its scheduled run time (Smith, 2019).
White, (2020) asserted that high availability indicates that the equipment is consistently operational and ready for use during scheduled production times. This leads to increased productivity and efficiency in manufacturing processes. On the other hand, low availability can result from various factors such as breakdowns, unplanned maintenance, setup and adjustment times, and other unexpected downtime events. Improving availability as a measure of OEE involves implementing strategies to minimize downtime and maximize uptime. This can include preventive maintenance programs to address potential issues before they cause breakdowns, optimizing changeover processes to reduce setup times, investing in spare parts inventory to quickly address equipment failures, and utilizing predictive maintenance technologies to anticipate maintenance needs. By focusing on improving availability as part of OEE calculations, manufacturers can enhance overall equipment performance, increase productivity, reduce costs associated with downtime, and ultimately improve their competitiveness in the market (Lee, 2018).

Performance
Performance as a measure of Overall Equipment Effectiveness (OEE) is a crucial concept in the field of manufacturing and production management. OEE is a metric used to evaluate how effectively a manufacturing operation is utilized by measuring the percentage of planned production time that is truly productive. It provides insights into the efficiency and effectiveness of equipment and processes on the shop floor. Performance, one of the three factors that make up OEE (along with availability and quality), plays a significant role in determining the overall productivity and profitability of a manufacturing operation (White, 2020).
Performance in the context of OEE refers to the speed at which a machine or process operates compared to its maximum potential speed. It takes into account factors such as cycle time, downtime, and speed loss to assess how well equipment is performing relative to its optimal capacity. By analyzing performance as part of OEE calculations, manufacturers can identify opportunities for improvement, optimize production schedules, reduce bottlenecks, and enhance overall operational efficiency. Measuring performance as part of OEE involves tracking key performance indicators (KPIs) such as cycle time, throughput rate, and utilization rate. These metrics help managers understand how efficiently equipment is running and where potential inefficiencies lie. By monitoring performance metrics in real-time or through historical data analysis, organizations can pinpoint areas for improvement and implement strategies to boost productivity (Johnson, 2015).
Brown,.(2017) Improving performance as a component of OEE requires a holistic approach that considers factors such as maintenance practices, operator training, process optimization, and technology upgrades. By investing in predictive maintenance tools, automation technologies, and continuous improvement initiatives, manufacturers can enhance equipment performance and drive overall equipment effectiveness. In conclusion, performance is a critical aspect of Overall Equipment Effectiveness (OEE) that directly impacts the efficiency and productivity of manufacturing operations. By measuring and improving performance metrics within the framework

of OEE, organizations can optimize their production processes, reduce waste, and achieve higher levels of operational excellence.

Quality

Quality is a crucial component of Overall Equipment Effectiveness (OEE), a metric used in manufacturing and production industries to assess the efficiency and productivity of equipment. OEE is calculated by multiplying three factors: Availability, Performance, and Quality. Quality, as one of these factors, measures the rate at which products are produced without defects or rework. It reflects the effectiveness of the production process in maintaining high standards and minimizing waste (Smith, 2007).

Lee, (2018) Quality as a measure of OEE emphasizes the importance of producing goods that meet or exceed customer expectations. It involves ensuring that products are manufactured according to specifications, with minimal variations and defects. By focusing on quality within the OEE framework, organizations can improve their overall operational performance and customer satisfaction. To enhance quality within OEE calculations, companies often implement quality control measures such as regular inspections, testing procedures, and continuous improvement initiatives. By monitoring and addressing quality issues proactively, organizations can reduce downtime, improve throughput, and optimize resource utilization. In summary, quality plays a critical role in determining the overall effectiveness of equipment within the OEE framework. By prioritizing quality management practices and integrating them into OEE calculations, businesses can achieve higher levels of efficiency, reliability, and competitiveness in today's dynamic market environment.

A higher Quality score contributes to an overall higher OEE percentage, indicating better performance and efficiency in manufacturing operations. Conversely, a lower Quality score suggests areas for improvement in reducing defects, rework, or scrap within the production process. Improving Quality as a measure of OEE involves implementing strategies to minimize defects and enhance product quality. Organizations can focus on reducing scrap rates, conducting root cause analysis for defects, adopting quality control measures, leveraging technologies like computer vision for anomaly detection, and implementing corrective actions to enhance product quality (White, 2020).

By emphasizing Quality as part of OEE measurement and improvement initiatives, organizations can achieve several benefits. These include increased customer satisfaction due to higher-quality products, reduced waste from defective items or rework, improved operational efficiency through streamlined processes, and enhanced competitiveness in the market by delivering superior quality goods. In conclusion, Quality serves as a critical component of Overall Equipment Effectiveness (OEE) by evaluating the production of defect-free goods. By focusing on improving Quality within manufacturing processes, organizations can drive operational excellence, optimize resource utilization, and deliver high-quality products to meet customer expectations effectively (White, 2020).

Theoretical underpinning

Planned Maintenance (PM) theory

The theory of Planned Maintenance (PM) was propounded by T. P. M. Kanban in 1969. The theory of Planned Maintenance is a maintenance strategy that focuses on scheduling maintenance activities in advance to prevent equipment breakdowns and ensure optimal performance. The main assumptions of the theory include: Equipment failure can be predicted based on historical data and patterns. Regular maintenance activities can prevent sudden breakdowns. Scheduled maintenance is more cost-effective than reactive maintenance. Proper planning and scheduling of maintenance tasks can improve overall equipment reliability and performance.

Critiques of the Planned Maintenance theory include: Over-reliance on historical data: Critics argue that relying solely on historical data may not account for unforeseen circumstances or changes in operating conditions. Lack of flexibility: Some critics suggest that rigid maintenance schedules may not be suitable for all types of equipment or industries. Cost implications: Implementing a Planned Maintenance program can be costly, especially if it involves frequent inspections and replacements. The relevance of the Planned Maintenance theory to the study of Total Productive Maintenance (TPM) implementation and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers State lies in its emphasis on proactive maintenance practices. TPM builds upon the principles of Planned Maintenance by incorporating employee involvement, continuous improvement, and a holistic approach to equipment management. By implementing TPM practices, manufacturing firms in Rivers State can enhance their operational efficiency, reduce downtime, and improve overall equipment effectiveness. The Planned Maintenance (PM) approach, which emphasizes scheduled maintenance activities based on equipment condition monitoring and predictive maintenance techniques. PM helps organizations identify potential issues before they lead to breakdowns, thereby improving OEE by minimizing unplanned downtime.

Total Productive Maintenance Development (TPMD) model

Total Productive Maintenance Development (TPMD) model was propounded by Dr. Seiichi Nakajima in the 1960s. The TPMD model is a comprehensive approach to maintenance management that aims to maximize the productivity of equipment by involving all employees in the maintenance process. The theory is based on several key assumptions: Preventive Maintenance: Regular maintenance activities can prevent equipment breakdowns and improve overall equipment effectiveness. Employee Involvement: All employees, from operators to managers, should be involved in the maintenance process to ensure the success of TPM implementation. Continuous Improvement: TPM is a continuous improvement process that requires ongoing monitoring and adjustment to achieve optimal results. Overall Equipment Effectiveness (OEE): OEE is a key performance indicator used to measure the effectiveness of TPM implementation and identify areas for improvement.

Critiques of the TPMD model include: Resource Intensive: Implementing TPM can require significant resources in terms of time, money, and personnel, which may be challenging for some organizations. Resistance to Change: Employees may resist changes to established maintenance practices, making it difficult to fully implement TPM. Complexity: TPM implementation can be complex and may require specialized training and expertise, which could pose challenges for some organizations.

The relevance of the TPMD model to the study of Total Productive Maintenance (TPM) implementation and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers State lies in its ability to provide a structured framework for improving equipment reliability, reducing downtime, and increasing productivity. By following the principles of TPM outlined in the TPMD model, manufacturing firms in Rivers State can enhance their maintenance practices, engage employees at all levels, and ultimately improve their overall equipment effectiveness. Additionally, the Total Productive Maintenance Development (TPMD) model provides a structured framework for implementing TPM practices in manufacturing firms. This model includes steps such as establishing a TPM committee, conducting training programs, setting up autonomous maintenance teams, and implementing continuous improvement initiatives to enhance overall equipment effectiveness.

Empirical Review

Autonomous Maintenance and Overall Equipment Effectiveness (OEE)

Oyewobi, and Adebiyi (2018) undertook a study on Impact of Autonomous Maintenance on Overall Equipment Effectiveness in Nigerian Manufacturing Industries. Population of the study was

Nigerian manufacturing industries with a Sample Size of 150. Method of Data Analysis was Quantitative analysis using SPSS. The study found a significant improvement in Overall Equipment Effectiveness (OEE) after the implementation of Autonomous Maintenance practices. The study concluded that Autonomous Maintenance positively impacts OEE in Nigerian manufacturing industries. The authors recommend the widespread adoption of Autonomous Maintenance to enhance equipment effectiveness.

Okorie, and Nwankwo, (2017) carried out a study on assessment of Overall Equipment Effectiveness in Selected Nigerian Breweries" Population: Nigerian breweries Sample Size: 100 Method of Data Analysis: Statistical analysis and regression modeling Findings: The study revealed variations in Overall Equipment Effectiveness among different breweries, with factors like maintenance practices and workforce skill levels influencing OEE. Conclusion: There is a need for standardized maintenance practices and continuous skill development to improve OEE in Nigerian breweries. Recommendations: The authors suggest regular training programs for maintenance staff and the implementation of Autonomous Maintenance techniques.

Oladejo, and Adebayo, (2019) carried out a study on Impact of Autonomous Maintenance on Overall Equipment Effectiveness: A Case Study of a Nigerian Food Processing Company" Population: Employees in a Nigerian food processing company Sample Size: 80 Method of Data Analysis: Qualitative analysis through interviews and observations Findings: The study demonstrated a notable increase in Overall Equipment Effectiveness following the introduction of Autonomous Maintenance activities within the company. Conclusion: Autonomous Maintenance plays a crucial role in enhancing equipment performance and efficiency. Recommendations: The authors recommend the integration of Autonomous Maintenance as a standard practice across all departments within the company.

Adeniyi, and Ogundipe, (2020) undertook a study on exploring the Relationship Between Autonomous Maintenance and Overall Equipment Effectiveness: Evidence from the Nigerian Automotive Industry. Population of the study was Workers in the Nigerian automotive industry with a Sample Size of 120. Method of Data Analysis was Comparative analysis and correlation studies. The research uncovered a positive correlation between the implementation of Autonomous Maintenance and improvements in Overall Equipment Effectiveness within the automotive sector. The study concluded that embracing Autonomous Maintenance practices can lead to enhanced equipment performance and productivity in the Nigerian automotive industry. The authors suggest investing in training programs to equip workers with necessary skills for effective implementation of Autonomous Maintenance.

Ibrahim, and Yusuf, (2016) carried out a study on an Empirical Study on the Impact of Autonomous Maintenance on Overall Equipment Effectiveness: A Case Study of a Textile Company in Nigeria. Population of the study was employees at a textile company in Nigeria Sample Size with 70. Method of Data Analysis was Mixed-method approach involving surveys and equipment performance assessments. The study indicated a substantial enhancement in Overall Equipment Effectiveness following the adoption of Autonomous Maintenance strategies at the textile company. The study concluded that implementing Autonomous Maintenance can significantly boost equipment efficiency and reduce downtime in manufacturing operations. The authors propose regular monitoring and evaluation mechanisms to sustain the benefits derived from implementing Autonomous Maintenance practices.

Planned Maintenance and Overall Equipment Effectiveness (OEE)

Adebiyi, and Oke, (2018) undertook a study on Impact of Planned Maintenance on Overall Equipment Effectiveness in a Manufacturing Industry in Nigeria. Population of the study was Manufacturing industry workers in Nigeria with a Sample Size of 150. Method of Data Analysis was Quantitative analysis using statistical tools. The study found a significant positive relationship between planned maintenance activities and overall equipment effectiveness. The study concluded

that Planned maintenance plays a crucial role in enhancing overall equipment effectiveness in the manufacturing industry. The study recommended that emphasized the importance of implementing effective planned maintenance strategies to improve overall equipment effectiveness.
Oladele, and Adebayo, (2016) undertook a study on assessment of Planned Maintenance Practices and Overall Equipment Effectiveness in Selected Industries in Nigeria. Population of the study was various industries in Nigeria with a Sample Size of 200. Method of Data Analysis was Mixed-method approach combining qualitative and quantitative analysis. The study revealed that industries with well-implemented planned maintenance practices had higher overall equipment effectiveness levels. The study concluded that Effective planned maintenance practices are essential for optimizing overall equipment effectiveness in industries. The study suggested regular training programs for maintenance personnel to enhance planned maintenance practices.
Adewale, and Ogunnaike (2019) undertook a study on Impact of Planned Maintenance on Overall Equipment Effectiveness: A Case Study of a Nigerian Brewery. Population of the study was Employees at a Nigerian brewery with a Sample Size of 100. Method of Data Analysis was Case study analysis with qualitative data interpretation. The study demonstrated that proper implementation of planned maintenance led to improved overall equipment effectiveness at the brewery. Th study concluded that Effective planned maintenance significantly contributes to enhancing overall equipment effectiveness in industrial settings. The study recommended that Advocated for the adoption of preventive maintenance schedules to sustain high levels of overall equipment effectiveness.
Oyedepo, and Ajayi, (2017) undertook a study on evaluation of Planned Maintenance Strategies and Overall Equipment Effectiveness in the Oil and Gas Sector in Nigeria. Population of the study was Oil and gas sector employees in Nigeria with a Sample Size of 120. Method of Data Analysis was Comparative analysis between different planned maintenance strategies and their impact on overall equipment effectiveness. The study identified that predictive maintenance yielded the highest improvement in overall equipment effectiveness compared to other strategies. The study concluded that selecting appropriate planned maintenance strategies is crucial for optimizing overall equipment effectiveness, especially in the oil and gas sector. The study Recommended the adoption of predictive maintenance techniques for better performance outcomes.
Oni, and Olufemi, (2020) carried out a study on Effectiveness of Planned Maintenance on Overall Equipment Efficiency: A Study from the Construction Industry Perspective in Nigeria. Population of the study was Construction industry professionals in Nigeria with a Sample Size of 80. Method of Data Analysis was Qualitative content analysis. The study indicated that proactive planned maintenance practices positively influenced overall equipment efficiency within the construction industry context. The study concluded that Proactive planned maintenance is essential for improving overall equipment efficiency and productivity within the construction sector. The study recommended that Highlighted the need for regular monitoring and evaluation of planned maintenance activities to ensure sustained efficiency gains.

Quality Maintenance and Overall Equipment Effectiveness (OEE)
Oke, and Adebiyi, (2017) undertook a study on Quality Maintenance Practices and Overall Equipment Effectiveness in Nigerian Manufacturing Firms. Population of the study was Nigerian manufacturing firms with a Sample Size of 150. Method of Data Analysis was Survey questionnaire and statistical analysis. The study found a positive correlation between quality maintenance practices and overall equipment effectiveness in Nigerian manufacturing firms. The study concluded that Quality maintenance practices significantly impact the overall equipment effectiveness of manufacturing firms in Nigeria. The authors recommend that Nigerian manufacturing firms prioritize quality maintenance practices to improve their overall equipment effectiveness.

Oladele, and Oyedele, (2019) undertook a study on assessment of Quality Maintenance Strategies on Overall Equipment Effectiveness in Selected Manufacturing Companies in Nigeria. Population of the study was Selected manufacturing companies in Nigeria with a Sample Size of 200. Method of Data Analysis was Structured interviews and regression analysis. The study revealed that the implementation of quality maintenance strategies positively influences the overall equipment effectiveness of manufacturing companies in Nigeria. The study concluded that Quality maintenance strategies play a crucial role in enhancing the overall equipment effectiveness of manufacturing companies in Nigeria. Recommendation: The authors suggest that manufacturing companies in Nigeria should invest more resources in quality maintenance strategies to optimize their overall equipment effectiveness.

Adebayo, and Akintola, (2018) carried out a study on impact of Total Productive Maintenance on Overall Equipment Effectiveness in Nigerian Food Processing Industry. Population of the study was Nigerian food processing industry with a Sample Size of 100. Method of Data Analysis was Case study analysis and statistical modeling .The study demonstrated a significant improvement in overall equipment effectiveness following the implementation of Total Productive Maintenance practices in the Nigerian food processing industry. The study concluded that Total Productive Maintenance positively impacts the overall equipment effectiveness of companies operating in the Nigerian food processing sector. The authors recommend that food processing companies in Nigeria adopt Total Productive Maintenance practices to enhance their overall equipment effectiveness.

Adewale, and Lawal, (2020) carried out a study on enhancing Overall Equipment Effectiveness through Lean Manufacturing Practices in Nigerian Automotive Industry. Population of the study was Nigerian automotive industry with a Sample Size of 120. Method of Data Analysis was Observational study and performance metrics analysis. The research showed that implementing lean manufacturing practices can significantly improve the overall equipment effectiveness within the Nigerian automotive industry. The adoption of lean manufacturing practices is crucial for enhancing the overall equipment effectiveness within the Nigerian automotive sector. The authors recommend that automotive companies in Nigeria integrate lean manufacturing principles to optimize their overall equipment effectiveness.

Adeyemi, and Olufemi, (2016) carried out a study on Effectiveness of Quality Management Practices on Overall Equipment Efficiency in Selected Manufacturing Companies in Lagos State. Population of the study was Selected Manufacturing Companies in Lagos State with a Sample Size of 180. Method of Data Analysis was Questionnaire and Regression Analysis. The Study Found That Quality Management Practices Have A Positive Impact On Overall Equipment Efficiency In Selected Manufacturing Companies In Lagos State. The study concluded that Quality Management Practices Are Essential For Improving Overall Equipment Efficiency In Manufacturing Companies. The Authors Recommend That Manufacturing Companies In Lagos State Focus On Implementing Effective Quality Management Practices To Enhance Their Overall Equipment Efficiency.

METHODOLOGY

Cross sectional survey design was adopted for this study. . The population of this study is thirty two (32) manufacturing companies in Rivers State which are registered with the Rivers branch of Manufacturers Association of Nigeria (MAN). The list of the manufacturing firms is presented in Appendix I.

The sample size for this study is the thirty two (32) manufacturing companies earlier indicated as the population. The study adopted the census techniques. Three key managers (production manager, marketing manager and logistics manager) were chosen as respondents from each, of the thirty two firms is the sample. This gave us a total of ninety two (92) for the study. Primary data were collected expressly for a specific purpose by the investigator himself. This data gives the exact information wanted. Primary data mainly come from direct observation of events, manipulation of variables, performance of experiments and responses to questionnaire. The primary data for this study were generated through questionnaire.

Total Productive Maintenance (TPM) Implementation and Overall Equipment Effectiveness (OEE) in manufacturing firms questionnaire was independently subjected to content and construct validity by three Lecturers in the Department of Management, Faculty of Management Sciences, Ignatius Ajuru University of Education, Port Harcourt. The corrections and suggestions of the validators were effected on the finale copy of the instrument. The reliability of empirical measurement is indicated by the internal consistency, One of the most commonly used indicators of internal consistency is Cronbach's alpha coefficient. Questionnaire item statements with Cronbach's alpha reliability coefficient below the 0.70 threshold were eliminated. The test-re-test method was used. 20 copies of the questionnaire instrument were issue and some days later same copies were issue through electronic media. The results were used in computation using Cronbach's alpha test of reliability.

Reliability Statistics

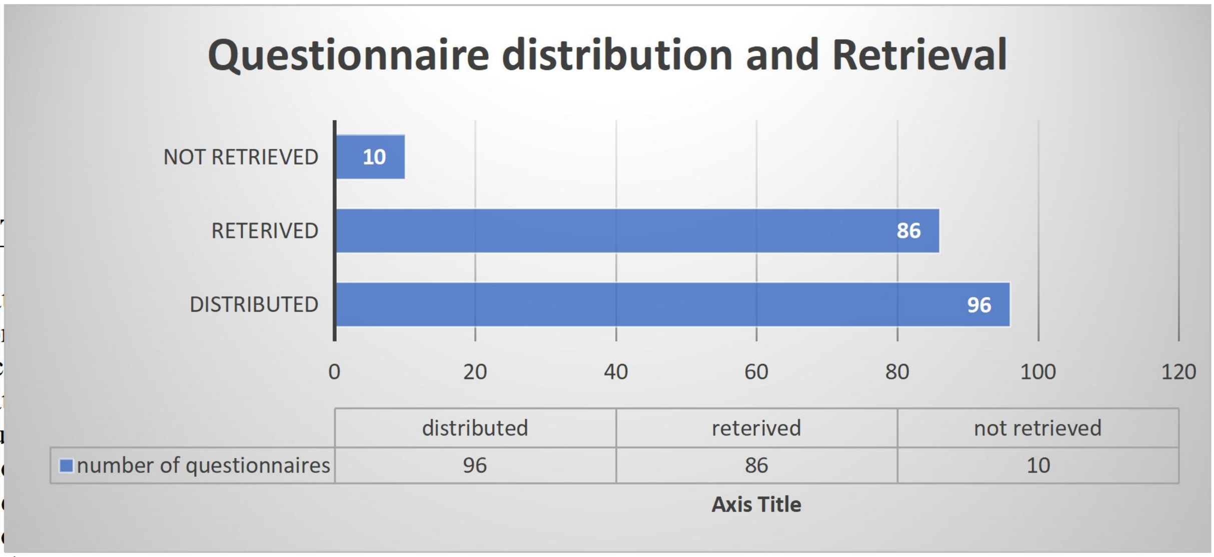
Cronbach's Alpha	N of Items
.806	6

Source: Researcher computation via SPSS version 25

The result of the Cronbach's Alpha reliability test indicates .806 which is above .70 which implies that the items are reliable. The research questions were analysis with the aid of descriptive statistics using mean and standard deviation while hypotheses were tested using Pearson product moment correlation on SPSS.

Data Presentation

1.



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How … downtime events attributed to failures in planned maintenance activities	86	1	5	296	3.44	1.289
Is there a documented plan for scheduled equipment inspections and repairs	86	2	5	320	3.72	1.155
Are there specific quality	86	2	5	345	4.01	1.068

	N	Min	Max	Sum	Mean	Std. Dev
metrics that have improved as a result of TPM practices						
The implementation of TPM contribute to overall product quality	86	1	5	306	3.56	1.428
Valid N (listwise)	86					

Source: Researcher survey data (2024) via SPSS v. 22

Table 1 revealed descriptive Statistics on total productive maintenance (TPM) implementation. Operators participate in equipment cleaning and lubrication tasks have a mean score of 3.73, operators receive adequate training on autonomous maintenance procedures have a mean score of 3.73, How often are equipment downtime events attributed to failures in planned maintenance activities have a mean score of 3.44, Is there a documented plan for scheduled equipment inspections and repairs have a mean score of 3.72, Are there specific quality metrics that have improved as a result of TPM practices have a mean score of 4.01, The implementation of TPM contribute to overall product quality have a mean score of 3.56. based on the criterion mean of 3.0 and since all our respective mean score is above 3.0, this implies that respondents agreed on the items of total productive maintenance (TPM) implementation in manufacturing firms in Rivers state.

Table 2: Descriptive Statistics on Overall Equipment Effectiveness (OEE)

	N	Min	Max	Sum	Mean	Std. Dev
The availability of equipment during scheduled production hours is adequate	86	1	5	294	3.42	1.241
How often does unplanned downtime occur in your production process	86	1	5	293	3.41	1.392
Do you track and analyze the performance of individual machines within your production line	86	1	5	275	3.20	1.291
How would you rate the quality of output produced by your equipment	86	1	5	295	3.43	1.232
To what extent do you believe that improving OEE can positively impact overall productivity	86	1	5	316	3.67	1.306
Generally, our Overall Equipment Effectiveness (OEE) is on the increasing side	86	1	5	280	3.26	1.520
Valid N (listwise)	86					

Source: Researcher survey data (2024) via SPSS v. 22

The availability of equipment during scheduled production hours is adequate have a mean score of 3.42, How often does unplanned downtime occur in your production process have a mean score of 3.41, Do you track and analyze the performance of individual machines within your production line have a mean score of 3.20, How would you rate the quality of output produced by your equipment have a mean score of 3.43, To what extent do you believe that improving OEE can positively impact overall productivity have a mean score of 3.67, Generally, our Overall Equipment Effectiveness (OEE) is on the increasing side have a mean score of 3.26. based on the criterion mean of 3.0 and since all our respective mean score is above 3.0, this implies that respondents agreed on the items of Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.

Research Hypotheses

The following null hypotheses were famulated and tested at a significance level of 0.05.

Ho₁: There is no significant relationship between Autonomous Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.

Table 3: Correlations between Autonomous Maintenance and Overall Equipment Effectiveness (OEE)

		Autonomous Maintenance	Overall Equipment Effectiveness (OEE)
Autonomous Maintenance	Pearson Correlation	1	.603**
	Sig. (2-tailed)		.000
	N	86	86
Overall Equipment Effectiveness (OEE)	Pearson Correlation	.603**	1
	Sig. (2-tailed)	.000	
	N	86	86

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

Ho₁: There is no significant relationship between Autonomous Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state (correlation. 1) reveals There is a significant relationship between Autonomous Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state (where rho = .603 and p =0.000) and based on the decision rule of $p < 0.05$ for null rejection; we reject the null hypothesis and restate *that there is a significant relationship between Autonomous Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.*

Ho₂: There is no significant relationship between Planned Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.

Table 4: Correlations between Planned Maintenance and Overall Equipment Effectiveness (OEE)

	Planned Maintenance	Overall Equipment Effectiveness (OEE)

Planned Maintenance	Pearson Correlation	1	.390**
	Sig. (2-tailed)		.000
	N	86	86
Overall Equipment Effectiveness (OEE)	Pearson Correlation	.390**	1
	Sig. (2-tailed)	.000	
	N	86	86

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

Ho2:: There is no significant relationship between Planned Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state (correlation 2) reveals There is a significant relationship between Planned Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state (where rho = .390 and p =0.000) and based on the decision rule of $p < 0.05$ for null rejection; we reject the null hypothesis and restate *that there is a significant relationship between Planned Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.*

Ho3: There is no significant relationship between Quality Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.

Table 5: Correlations between Quality Maintenance and Overall Equipment Effectiveness (OEE)

		Quality Maintenance	Overall Equipment Effectiveness (OEE)
Quality Maintenance	Pearson Correlation	1	.639**
	Sig. (2-tailed)		.000
	N	86	86
Overall Equipment Effectiveness (OEE)	Pearson Correlation	.639**	1
	Sig. (2-tailed)	.000	
	N	86	86

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

Ho3:: There is no significant relationship between Quality Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state (correlation 3) reveals There is a significant relationship between Quality Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state (where rho = .639 and p =0.000) and based on the decision rule of $p < 0.05$ for null rejection; we reject the null hypothesis and restate *that there is a significant relationship between Quality Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.*

Summary of findings

1. There is a significant relationship between Autonomous Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.
2. There is a significant relationship between Planned Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.
3. There is a significant relationship between Quality Maintenance and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.

CONCLUSION

The study concluded that there is a positive relationship between Total Productive Maintenance (TPM) Implementation and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state hence implementing Total Productive Maintenance (TPM) with a focus on Autonomous Maintenance, Planned Maintenance, Quality Maintenance, and enhancing Overall Equipment Effectiveness (OEE) will drive operational excellence and competitive advantage for manufacturing firms in Rivers state.

RECOMMENDATIONS

The following recommendations were drawn from the findings of the study:

i. Manufacturing firms should develop a comprehensive TPM implementation plan tailored to the specific needs and challenges of manufacturing firms in Rivers state.
ii. Manufacturing firms should provide extensive training programs for employees at all levels to ensure understanding and commitment to TPM principles.
iii. Manufacturing firms should establish clear communication channels to facilitate collaboration between maintenance teams, production teams, and management.
iv. Manufacturing firms should implement robust data collection systems to monitor OEE metrics accurately and identify areas for improvement.
v. Manufacturing firms should continuously review and refine TPM strategies based on feedback from employees and performance indicators to drive sustainable improvements in equipment reliability and operational efficiency.

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APPENDIX B
Letter of Introduction

I am a Ph.D student in Ignatius Ajuru university of Education , faculty of management sciences, Department of management. I am carrying out a study on **Total Productive Maintenance (TPM) Implementation and Overall Equipment Effectiveness (OEE) in manufacturing firms in Rivers state.** I will appreciate your honest response as it will be confidential and strictly for academic purposes only.

INSTRUCTION 1: *For section "A", please tick (√) as appropriate*

SECTION A: PERSONAL INFORMATION

1. Name of firm: ……………………………………………………………….
2. Gender: (i) Male ☐ (ii) Female ☐
3. Marital status: (i) Single ☐ (ii) Married ☐

NOTE: *strongly agree (SA) =5; agree (A) = 4; undecided (U) = 3; disagree (D) =2; strongly disagree (SD) =1*

SECTION B: Total Productive Maintenance (TPM) Implementation

S/N	Item Statement	SA	A	U	SD	D
1.	operators participate in equipment cleaning and lubrication tasks					
2.	operators receive adequate training on autonomous maintenance procedures					
3.	How often are equipment downtime events attributed to failures in planned maintenance activities					
4	Is there a documented plan for scheduled equipment inspections and repairs					
5	Are there specific quality metrics that have improved as a result of TPM practices					
6	The implementation of TPM contribute to overall product quality					

SECTION C: Overall Equipment Effectiveness (OEE)

S/N	Item Statement	SA	A	U	SD	D

1	The availability of equipment during scheduled production hours is adequate					
2	How often does unplanned downtime occur in your production process					
3	Do you track and analyze the performance of individual machines within your production line					
4	How would you rate the quality of output produced by your equipment					
5	To what extent do you believe that improving OEE can positively impact overall productivity					
6	Generally, our Overall Equipment Effectiveness (OEE) is on the increasing side					

Appendix B
SPSS output

Warning # 849 in column 23. Text: en_NG
The LOCALE subcommand of the SET command has an invalid parameter. It could not be mapped to a valid backend locale.
DESCRIPTIVES VARIABLES=VAR00001 VAR00002 VAR00003 VAR00004 VAR00005 VAR00006
/STATISTICS=MEAN SUM STDDEV MIN MAX.

Descriptive

Notes

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Comments		
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	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	86
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	All non-missing data are used.
Syntax		DESCRIPTIVES VARIABLES=VAR00001 VAR00002 VAR00003 VAR00004 VAR00005 VAR00006 /STATISTICS=MEAN SUM STDDEV MIN MAX.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.03

[DataSet0]

Descriptive Statistics

	N	Minimum	Maximum	Sum	Mean	Std. Deviation

operators participate in equipment cleaning and lubrication tasks	86	2	5	321	3.73	1.034
operators receive adequate training on autonomous maintenance procedures	86	2	5	321	3.73	1.278
How often are equipment downtime events attributed to failures in planned maintenance activities	86	1	5	296	3.44	1.289
Is there a documented plan for scheduled equipment inspections and repairs	86	2	5	320	3.72	1.155
Are there specific quality metrics that have improved as a result of TPM practices	86	2	5	345	4.01	1.068
The implementation of TPM contribute to overall product quality	86	1	5	306	3.56	1.428
Valid N (listwise)	86					

```
FREQUENCIES VARIABLES=VAR00001 VAR00002 VAR00003 VAR00004 VAR00005 VAR00006
  /STATISTICS=STDDEV MINIMUM MAXIMUM MEAN SUM
  /ORDER=ANALYSIS.
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Frequencies

Notes

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	Cases Used	Statistics are based on all cases with valid data.
Syntax		FREQUENCIES VARIABLES=VAR00001 VAR00002 VAR00003 VAR00004 VAR00005 VAR00006 /STATISTICS=STDDEV

		MINIMUM MAXIMUM MEAN SUM /ORDER=ANALYSIS.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.02

Statistics

		operators participate in equipment cleaning and lubrication tasks	operators receive adequate training on autonomous maintenance procedures	How often are equipment downtime events attributed to failures in planned maintenance activities	Is there a documented plan for scheduled equipment inspections and repairs	Are there specific quality metrics that have improved as a result of TPM practices	The implementation of TPM contribute to overall product quality
N	Valid	86	86	86	86	86	86
	Missing	0	0	0	0	0	0
Mean		3.73	3.73	3.44	3.72	4.01	3.56
Std. Deviation		1.034	1.278	1.289	1.155	1.068	1.428
Minimum		2	2	1	2	2	1
Maximum		5	5	5	5	5	5
Sum		321	321	296	320	345	306

Frequency Table

operators participate in equipment cleaning and lubrication tasks

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	12	14.0	14.0	14.0
	3	24	27.9	27.9	41.9
	4	25	29.1	29.1	70.9
	5	25	29.1	29.1	100.0
	Total	86	100.0	100.0	

operators receive adequate training on autonomous maintenance procedures

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	24	27.9	27.9	27.9

	3	12	14.0	14.0	41.9
	4	13	15.1	15.1	57.0
	5	37	43.0	43.0	100.0
	Total	86	100.0	100.0	

How often are equipment downtime events attributed to failures in planned maintenance activities

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	12	14.0	14.0	14.0
	2	12	14.0	14.0	27.9
	4	50	58.1	58.1	86.0
	5	12	14.0	14.0	100.0
	Total	86	100.0	100.0	

Is there a documented plan for scheduled equipment inspections and repairs

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	24	27.9	27.9	27.9
	4	38	44.2	44.2	72.1
	5	24	27.9	27.9	100.0
	Total	86	100.0	100.0	

Are there specific quality metrics that have improved as a result of TPM practices

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	2	12	14.0	14.0	14.0
	3	12	14.0	14.0	27.9
	4	25	29.1	29.1	57.0
	5	37	43.0	43.0	100.0
	Total	86	100.0	100.0	

The implementation of TPM contribute to overall product quality

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	13	15.1	15.1	15.1
	3	36	41.9	41.9	57.0
	5	37	43.0	43.0	100.0

Total	86	100.0	100.0	

```
FREQUENCIES VARIABLES=VAR00001 VAR00002 VAR00003 VAR00004 VAR00005 VAR00006
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  /ORDER=ANALYSIS.
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Frequencies

Notes

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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data.
Syntax		FREQUENCIES VARIABLES=VAR00001 VAR00002 VAR00003 VAR00004 VAR00005 VAR00006 /STATISTICS=STDDEV MINIMUM MAXIMUM MEAN SUM /ORDER=ANALYSIS.
Resources	Processor Time	00:00:00.03
	Elapsed Time	00:00:00.03

Statistics

		The availability of equipment during scheduled production hours is adequate	How often does unplanned downtime occur in your production process	Do you track and analyze the performance of individual machines within your production line	How would you rate the quality of output produced by your equipment	To what extent do you believe that improving OEE can positively impact overall productivity	Generally, our Overall Equipment Effectiveness (OEE) is on the increasing side
N	Valid	86	86	86	86	86	86
	Missing	0	0	0	0	0	0
Mean		3.42	3.41	3.20	3.43	3.67	3.26
Std. Deviation		1.241	1.392	1.291	1.232	1.306	1.520
Minimum		1	1	1	1	1	1

Maximum	5	5	5	5	5	5
Sum	294	293	275	295	316	280

Frequency Table

The availability of equipment during scheduled production hours is adequate

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	6	7.0	7.0	7.0
	2	16	18.6	18.6	25.6
	3	21	24.4	24.4	50.0
	4	22	25.6	25.6	75.6
	5	21	24.4	24.4	100.0
	Total	86	100.0	100.0	

How often does unplanned downtime occur in your production process

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	6	7.0	7.0	7.0
	2	25	29.1	29.1	36.0
	3	12	14.0	14.0	50.0
	4	14	16.3	16.3	66.3
	5	29	33.7	33.7	100.0
	Total	86	100.0	100.0	

Do you track and analyze the performance of individual machines within your production line

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	12	14.0	14.0	14.0
	2	19	22.1	22.1	36.0
	3	4	4.7	4.7	40.7
	4	42	48.8	48.8	89.5
	5	9	10.5	10.5	100.0
	Total	86	100.0	100.0	

How would you rate the quality of output produced by your equipment

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	3	3.5	3.5	3.5
	2	27	31.4	31.4	34.9
	3	4	4.7	4.7	39.5

	4	34	39.5	39.5	79.1
	5	18	20.9	20.9	100.0
	Total	86	100.0	100.0	

To what extent do you believe that improving OEE can positively impact overall productivity

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	6	7.0	7.0	7.0
	2	15	17.4	17.4	24.4
	3	10	11.6	11.6	36.0
	4	25	29.1	29.1	65.1
	5	30	34.9	34.9	100.0
	Total	86	100.0	100.0	

Generally, our Overall Equipment Effectiveness (OEE) is on the increasing side

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	18	20.9	20.9	20.9
	2	6	7.0	7.0	27.9
	3	28	32.6	32.6	60.5
	4	4	4.7	4.7	65.1
	5	30	34.9	34.9	100.0
	Total	86	100.0	100.0	

DESCRIPTIVES VARIABLES=VAR00001 VAR00002 VAR00003 VAR00004 VAR00005 VAR00006
/STATISTICS=MEAN SUM STDDEV MIN MAX.

Descriptives

Notes

Output Created		23-APR-2024 04:39:47
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	86
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	All non-missing data are used.
Syntax		DESCRIPTIVES VARIABLES=VAR00001 VAR00002 VAR00003 VAR00004

		VAR00005 VAR00006 /STATISTICS=MEAN SUM STDDEV MIN MAX.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.03

Descriptive Statistics

	N	Minimum	Maximum	Sum	Mean	Std. Deviation
The availability of equipment during scheduled production hours is adequate	86	1	5	294	3.42	1.241
How often does unplanned downtime occur in your production process	86	1	5	293	3.41	1.392
Do you track and analyze the performance of individual machines within your production line	86	1	5	275	3.20	1.291
How would you rate the quality of output produced by your equipment	86	1	5	295	3.43	1.232
To what extent do you believe that improving OEE can positively impact overall productivity	86	1	5	316	3.67	1.306
Generally, our Overall Equipment Effectiveness (OEE) is on the increasing side	86	1	5	280	3.26	1.520
Valid N (listwise)	86					

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CORRELATIONS
  /VARIABLES=VAR00001 VAR00002
  /PRINT=TWOTAIL NOSIG
  /MISSING=PAIRWISE.
```

Notes

Output Created	23-APR-2024 04:55:25

Comments		
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	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	86
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.
Syntax		CORRELATIONS /VARIABLES=VAR00001 VAR00002 /PRINT=TWOTAIL NOSIG /MISSING=PAIRWISE.
Resources	Processor Time	00:00:00.06
	Elapsed Time	00:00:00.05

```
CORRELATIONS
  /VARIABLES=VAR00001 VAR00002
  /PRINT=TWOTAIL NOSIG
  /MISSING=PAIRWISE.
```

Correlations

Notes

Output Created		23-APR-2024 04:55:57
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	86
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.
Syntax		CORRELATIONS /VARIABLES=VAR00001 VAR00002 /PRINT=TWOTAIL NOSIG /MISSING=PAIRWISE.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

Correlations

		Autonomous Maintenance	Overall Equipment Effectiveness (OEE)
Autonomous Maintenance	Pearson Correlation	1	.603**
	Sig. (2-tailed)		.000
	N	86	86
Overall Equipment Effectiveness (OEE)	Pearson Correlation	.603**	1
	Sig. (2-tailed)	.000	
	N	86	86

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

```
CORRELATIONS
  /VARIABLES=VAR00001 VAR00002
  /PRINT=TWOTAIL NOSIG
  /MISSING=PAIRWISE.
```

Correlations

Notes

Output Created		23-APR-2024 05:02:47
Comments		
Input	Active Dataset	DataSet0
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	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	86
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.
Syntax		CORRELATIONS /VARIABLES=VAR00001 VAR00002 /PRINT=TWOTAIL NOSIG /MISSING=PAIRWISE.
Resources	Processor Time	00:00:00.03
	Elapsed Time	00:00:00.05

Correlations

		Planned Maintenance	Overall Equipment Effectiveness (OEE)
Planned Maintenance	Pearson Correlation	1	.390**
	Sig. (2-tailed)		.000
	N	86	86
Overall Equipment Effectiveness (OEE)	Pearson Correlation	.390**	1
	Sig. (2-tailed)	.000	
	N	86	86

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

```
CORRELATIONS
  /VARIABLES=VAR00001 VAR00002
  /PRINT=TWOTAIL NOSIG
  /MISSING=PAIRWISE.
```

Correlations

Notes

Output Created		23-APR-2024 05:05:36
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	86
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.
Syntax		CORRELATIONS /VARIABLES=VAR00001 VAR00002 /PRINT=TWOTAIL NOSIG /MISSING=PAIRWISE.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.19

Correlations

		Quality Maintenance	Overall Equipment Effectiveness (OEE)
Quality Maintenance	Pearson Correlation	1	.639**

	Sig. (2-tailed)		.000
	N	86	86
Overall Equipment Effectiveness (OEE)	Pearson Correlation	.639**	1
	Sig. (2-tailed)	.000	
	N	86	86

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

APPENDIX C
LIST OF STUDIED MANUFACTURING FIRMS IN RIVERS STATE

S/No.	Name of Firm and Address	Product Manufactured
1	Air Liquide Nigeria Plc., Plot 108, Trans Amadi Layout Port Harcourt	Industrial and medical gases and welding equipment.
2	Almarine Limited, 28, Kolokuma street Borokiri Port Harcourt	Outboard engine Boats
3	Crocodile Matchets Nig, Ltd., Plot 29, Trans Amadi layout, Port Harcourt	Matchets
4	La Sien Bottling company Ltd, Trans Amadi Port Harcourt	Water
5	Eastern Enamelware Factory Ltd., Plot 29, Trans Amadi Layout, Port Harcourt	Household cooking utensils
6	Rivers vegetable Oil Co. Ltd., Plot 80, Trans Amadi Layout, Port Harcourt	Vegetable edible oil
7	General Agro Ind. Limited, Plot 78/79, Trans Amadi Layout, Port Harcourt	Edible vegetable oil and palm kernel pellets
8	First Aluminum Nig. Ltd., Plot 19-21, Trans Amadi Layout, Port Harcourt	Aluminum coils, sheets & circle collapsible
9	Nigeria Bottling Co. Plc., Plot 126, Trans Amadi layout, Port Harcourt	Coca-cola, krest, Bitter lemon, sprite & fanta
10	Nigerian Engineering Work Ltd., Trans Amadi Layout, Port Harcourt	Steel structure and pipes, pressure vessels, filling cabinets, cupboards, wardrobe, chairs and desk library shelving, storage shelving, industrial lockers and Fabrication.
11	PH Flour Mills limited, 8A, Industry Road Port Harcourt	Flour and maizelina, semolina, bran
12	QR Manufacturing and trading limited, Plot 75, Trans Amadi Layout, Port Harcourt	Motor vehicle radiators
13	Sun Flower Manufacturing Company Ltd., Plot 70, Trans Amadi Layout, Port Harcourt	Plastic bags, containers and household utensils
14	Shower Limited, 17, Ohaeto Street, D-line Port Harcourt	Safety and related uniforms & others
15	Polo Packaging Ind. Ltd., Plot 84 Trans Amadi Layout, Port Harcourt	Polopropylene woven bags & packaging materials
16	Nikko Industries Nig. Ltd., Choba, Port Harcourt.	Nylon Fishnets, Auto Trawl Net
17	Galba Limited, Plot 311, Trans Amadi layout,	Refurbished Flat 682 T3-N3 truck,

	Port Harcourt	Trailer axles flat 682 T3-N3 Engine refurbishing of Diesel & Gas, Turbine engine, power plant & truck spares.
18	Oil &Industrial Services Ltd., 9A, Trans Amadi layout, Port Harcourt	Gears, shafts, bolts & nuts, Flanges, bushings
19	Crushed Rock Nig. Ltd., PH/Aba Expressway Port Harcourt	Granite block & Aggregates
20	Danelec Limited, Plot 278, Trans Amadi Layout, Port Harcourt	Electrical/ Electronic Regulators
21	Dangote Bail Ltd., Onne, Port Harcourt	Cement
22	Keedak Nig. Ltd., Plot 18, Trans Amadi Layout, Port Harcourt	Specialty chemical & water treatment application
23	CWAY Port Harcourt Co. Limited, Elelenwo, Port Harcourt	Water
24	Boskel Nigeria Limited, PH/Aba Expressway Port Harcourt	Smokeless Flares for the oil 7 glass industry
25	Eastern Wrought Iron Limited, Plot 47, Trans Amadi layout, Port Harcourt	Bunk beds, wrought iron furniture, hospital & school furniture, star foam, industry and domestic tanks
26	Dufil prima Foods Ltd., Plot 29, Trans Amadi layout, Port Harcourt	Indomie Instant Noodles brands
27	Far East Paint Lustre Ind. Ltd., Plot 170/171, Trans Amadi Layout, Port Harcourt	Paints & painting materials, ink, polish colouring & shading, mixture dyes, pigments, varnishes Resins
28	Hoison Energy & Resources Serv. Ltd., Trans Amadi Layout, Port Harcourt	High Density polyproethylene plastics & high density polypylene waste bags
29	Chief Ellah & Sons Nig. Ltd., 13, Force Avenue, Port Harcourt	Fish & animal products
30	Best Aluminum Mfg Co. Ltd., 85, Aba Road Port Harcourt	Aluminum roofing sheets & cooking utensils
31	Eleme petrochemicals company Ltd., Eleme, Port Harcourt	Polypropylene, polyprothylene
32	Delta plastic Ltd., Industrial complex, Apa Ogwu Road, off R.D road, Rumuodara, Port Harcourt	Poly bags, Bopp brand wrappers, pure water films, shopping bags, pet bottles, disposals, plates

Source: Members of Manufacturers Association of Nigeria, Rivers/Bayelsa Branch, 2021