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Improving Productivity in Automotive Manufacturing: A Combined Approach of Root Cause Analysis and Sem Models

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study investigates the root causes of productivity decline in the automotive assembly section of a Nigerian industry, and proposes revitalization strategies and optimization models. Mismanagement in productivity measures, particularly in labour and capital, is a major cause of failure in manufacturing industries. The research methodology of this study utilized data collected through questionnaires, company records, and analyzed using Excel and MATLAB software, afterward, regression and SEM models were applied. From the result obtained, political factors, machine failure, and financial challenges were identified as the top root causes, with impacts of

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20%, 18%, and 15% respectively. The models showed a good fit, with regression and SEM estimates of 95% and 90%. The recommended strategies indicated a direct relationship with the case study company and other manufacturing company factors and sections that makes up an industry, indicating a positive revitalization techniques and maintenance sustainability. The study recommends strategies include financial restructuring and technological innovation to enhance operational efficiency and align with industry standards.

Keywords: Productivity; maintenance; innovation; efficiency; optimization.

1. INTRODUCTION

Productivity decline in manufacturing industries is a well-documented phenomenon, often attributed to factors such as outdated machinery, inadequate maintenance, shifts in market dynamics, government decisions and may other factors [1,2]. Nigeria as a great nation tagged as 'Giant of Africa' has witnessed some manufacturing and service rendering company collapse due some of these factors mentioned, some of these company cause and year of their closure includes: Errand Products failed due to foreign exchange scarcity in the year 2019, GlaxoSmithKline Nigeria failed due to high production cost in 2019, Multi-Trex Integrated Foods Plc failed due to bank debt in 2015, Nasco Fibre failed due to poor business environment in 2020, and Universal Rubber failed due to policy inconsistency in 2019 [3,4].

Automotive industry is a dynamic sector that have operation sections such as body shop, assembly line paint shop, quality control, and logistics and supply chain management [5,6]. Automotive industry significantly contributes to global economies through the manufacturing of vehicles and related components, which have profound implications for employment, economic growth, and industrial development [7-9]. Automotive industry faces challenges such as technological advancements, regulatory changes, and shifts in consumer preferences, which require continuous innovation and strategic adjustments, Table 1 presents some automotive companies that failed due to mismanagement of forces.

To cub these unexpected decline and failure in automotive company, some exceptional researches have been conducted to forecast, predict, maintain smooth production processes, supply chain management, planned and unplanned, packaging and other sections and subsection operations to attract optimization and increase productivity in automotive industry, such as Theissler et al. [10] discussed recent advancements in maintenance modeling, particularly focusing on data-driven approaches like machine learning (ML) in the automotive industry. They highlighted the emergence of predictive maintenance (PdM) as a crucial strategy for ensuring functional safety in vehicles while minimizing maintenance costs. They noted that ML is particularly well-suited for PdM due to the vast amounts of operational data modern vehicles generate [11-13].

Table 1. Automotive industries that have failed or collapsed, year of failure, and causes [14-16]

S/N	Company Name	Year of Failure	Cause of Failure
1	DeLorean Motor Company	1982	Financial difficulties, lack of funds to continue production
2	SAAB	2011	Financial issues and inability to compete in the global market
3	Pontiac	2010	Decline in sales, restructuring of General Motors
4	Hummer	2010	Poor sales and high production costs
5	Saturn	2010	Low sales and restructuring of General Motors
6	Studebaker	1966	Financial problems and inability to modernize
7	American Motors Corporation (AMC)	1988	Financial issues and competition from larger manufacturers
8	Packard	1958	Financial difficulties, poor management decisions
9	Oldsmobile	2004	Declining sales and brand consolidation by General Motors
10	Fisker Automotive	2013	Financial difficulties and inability to meet production goals

Zonta et al. [17] researched on the evolution of Industry 4.0 in the automotive sector, emphasizing the shift in maintenance paradigms. It introduces concepts like predictive maintenance and condition-based maintenance (CBM) and explores their applications in revolutionizing automotive maintenance. Business process management (BPM) and business process model and notation (BPMN) methodologies are also introduced in relation to maintenance processes. A case study of Renault Cacia implementing these concepts is presented, showcasing the benefits of proactive maintenance strategies. The conclusion highlights practical and theoretical contributions, including cost savings and increased productivity. The article suggests future research directions, such as applying AI technologies for predictive maintenance and exploring hybrid systems combining human decision-making with machine learning capabilities [18-20].

Gstalter et al. [21] developed a new method for extracting the index of nodes and snapshots using the empirical interpolation method (EIM) to compute a reduced order model (ROM) much faster than previous methods. Their approach reduced the computational time significantly, allowing a ROM to be computed in 20 minutes on 24 cores, compared to 60 minutes with the previous clustering method. This method drastically reduced the number of simulations needed, from over 100 to just 6, to find a configuration that meets specifications. They also improved decision-making processes by creating a ROM-based surrogate model that minimized the need for extensive car crash simulations. Future developments will focus on parallelizing the EIM algorithm and considering multiple crash scenarios and parameters to further enhance the method's efficiency and applicability. The research highlights the importance of understanding and analyzing the vast amounts of data produced by finite elements (FE) simulations using non-intrusive methods to extract knowledge and optimize designs efficiently [22–25].

Haris and Junoh [26] researched on linear programming (LP) approach to profit maximization in the automotive industry, specifically for the Vehicle Lighting Company. The study demonstrates how mathematical optimization models can effectively address budgetary tasks and enhance cost-effectiveness in industrial operations [27,28]. By employing LP, the research aims to optimize production planning for six original equipment manufacturer (OEM) products, considering five objective constraints and nine slack variables. The established LP model provides valuable insights into production quantity planning, ensuring maximum profit. It highlights the model's usefulness as a decision-making tool for prioritizing products, leading to optimal profit and cost reduction for the company [29].

While existing studies have provided valuable insights into various factors influencing the declined productivity of automotive industries. Moreover, the review showcased some models and maintenance systems that will attract an optimized system of automotive industry, however, there remains a notable gap in the literature regarding the integration and holistic analysis of these factors. The proposed research aims to bridge this gap by conducting a comprehensive investigation on the causes of failure of case study automotive assembling industry in Nigeria, afterward some optimization model like regression model and structural equation models (SEM) was applied. The study will contribute to the existing manufacturing and service rendering industries of knowledge by offering practical insights and recommendations for mitigating risks of declining in productivity and collapsed companies.

2. MATERIALS AND METHODS

Brief Overview about the Case Study Company:

The Automotive Assembly Company Nigeria was originally a joint venture between the Nigerian federal government and Daimler-Benz (Germany). The initial shareholders included Daimler-Benz, G.U.O. & Sons Ltd, various Nigerian state finance ministries, and Nigerian citizens. After Germany's withdrawal in 2007, the company became fully Nigerian-owned. Incorporated in 1977 and operational since 1981, Automotive Assembly Company Nigeria has significantly contributed to Nigeria's industrial growth. The plant, located in Emene, Enugu, spans 300,000 square meters and exemplifies successful economic and technological cooperation between Nigeria and Germany. On the area of the staff strength of the company, based on the gathered investigations, the company rose to about 794 workers in 1994 which included 12 expatriates. Table 2 presents the company’s different automobile models.

Table 2. Overview of automobile models and configurations

S/N	Automobile Model Name	Configuration
1	MB TRUCKS	5-38 Metric Tons Gross Weight
2	MB 0131	42 Seaters City/Intercity Buses
3	MB 0400R	Intercity Buses, 49 Seaters
4	MB 04400RS	53-Seater Intercity Bus
5	MB 0400RSD	56-Seater Intercity Bus
6	MB 0911	56-Seater Bus
7	MB 01414	61-Seater Bus
8	MB 01520	52-Seater Bus
9	MB 01635	52-Seater Bus
10	Fire Fighting Vehicles	-
11	Ambulances	-
12	Mobile Clinics	-
13	Refuse Disposal Vehicles	-
14	Vehicle Refurbishment	-

Source: Company's journal and library.

The production processes of the company are the same for both the Buses and the Trucks. The production process is divided into two parallel lines of activities namely the central workshop (body shop) and the chassis assembly Line. The Body Shop has the tyre assembly, pre-skeleton area, skeleton formation, skeleton line paneling, seat frame, upholstery area, door manufacturing section and the metal finishing section where all the metal joints are finished by filling and smoothening all the joints and edges. Table 3 presents the machines and tools used in each manufacturing lines.

Table 3. Presents the machines used in manufacturing lines

Process Stage	Body Shop Machines	Chassis Assembly Line Machines
Welding	Robotic Spot-Welding Machines	Robotic Welding Cells for Chassis Components
	Resistance Spot Welding Machines	MIG (Metal Inert Gas) Welding Stations
	Laser Welding Machines	Sub-Assembly Welding Stations
Cutting and forming	CNC Laser Cutting Machines	CNC Tube Bending Machines
	Hydraulic Presses	Stamping Presses for Chassis Parts
	Plasma Cutting Machines	Roll Forming Machines for Chassis Components
Assembly and Joining	Robotic Assembly Cells	Automated Chassis Assembly Line
	Automated Riveting Machines	Nut and Bolt Tightening Stations
	Adhesive Application Systems	Chassis Component Integration Stations
	Nut and Bolt Feeding Systems	Frame Alignment Machines
Inspection and Testing	Vision Inspection Systems	Quality Control Stations
	Coordinate Measuring Machines (CMM)	Load and Stress Testing Equipment
	Leak Testing Stations	Suspension and Brake Testing Stations
Surface Treatment	Paint Spraying Robots	Electrocoating (E-Coat) Systems for Corrosion Protection
	Phosphating and Cleaning Stations	Powder Coating Booths for Surface Finishing
Material Handling	Conveyor Systems	Automated Guided Vehicles (AGVs) for Part Transport
	Robotic Material Handling Systems	Lift and Transfer Systems for Chassis Components

Source: Maintenance and Inventory Records Department.

In a nutshell, the metal finishing stage ends the bodywork, which is then moved by a crane to the paint shop, afterward, the vehicle body is degreased, washed, dried, treated with primer and fillers, washed again, dried, and painted. Next, it goes to the trim-line, awaiting the chassis assembly. The chassis assembly line starts with frame assembly, axle mounting, and chassis turning. The chassis is then wedded to the body, and the engine is mounted. This completed vehicle undergoes brake tests and final inspection before moving to the showroom.

2.1 Materials

The materials used in conducting this research is presented in Table 4.

Table 4. Materials and their descriptions used in the study

S/N	Item	Description
1	Questionnaire Forms	Physical paper-based forms and electronic forms used to collect responses from participants.
2	Pens and Pencils	Writing instruments used for completing paper-based questionnaires.
3	Electronic Devices	Phones and other devices used for conducting electronic surveys.
4	Interview Guide or Protocol	A physical document containing a structured list of questions or topics for guiding the interviews.
5	Recording Devices	Audio recorders and video cameras used to capture interviews for later analysis.
6	Note-taking Materials	Notebooks or electronic devices used by interviewers to take notes during the interviews.
7	Recruitment Documents	Documents used to recruit participants for the study.
8	Informed Consent Forms	Written consent forms used to obtain participants' consent to partake in the study.
9	Data Analysis Software	Tools such as Excel for data visualization, SPSS for statistical analysis, and Mini MATLAB for quantitative analysis.
10	Company journals, magazines, and bulletins	Internal publications and data storage systems used for reference and information gathering.
11	Internet Research	Online research conducted to gather information and data relevant to the study
12	Maintenance Log Sheets	Documents detailing maintenance records used for data collection and analysis.

Fig. 1. The methodology steps

The selected materials presented in Table 4 played a crucial role in this research by providing comprehensive tools and resources for data collection, analysis, and validation. Questionnaires and interviews ensured diverse and reliable input from participants, while recording devices and note-taking materials preserved accurate details. Data analysis software facilitated robust quantitative and qualitative analysis, and reference materials from journals, libraries, and online research supported the study's theoretical foundation. This combination of materials enabled a thorough and effective research process, ensuring the validity and reliability of the findings.

2.2 Methods

The function of a research design is to ensure that the evidence obtained enables the researcher to effectively address the research problem logically and as unambiguously as possible. Fig. 1 illustrates the process flow chart of the research methodology.

2.2.1 Data collection

Structured questionnaires were distributed to current and former employees, customers, and analysts to gather insights into their experiences regarding the automotive company's productivity decline and collapse of the industry, ranging from 2012 – 2016. These questionnaires focused on observations related to machine failures, maintenance costs, digital skills utilization, and other factors contributing to the collapse of the automobile assembling sector. In-depth interviews with key stakeholders, including management personnel, engineers, and maintenance staff, provided a qualitative understanding of the challenges, particularly those related to machine maintenance and digital skills in manufacturing. Company magazines, bulletins, and data storage systems were analyzed to extract historical information and official communications about productivity issues, machine failures, and maintenance strategies. Electronic devices were used for conducting electronic surveys and interviews, while note-taking materials documented interview responses.

2.2.2 Data analysis

Quantitative data from financial reports were subjected to statistical analysis using Excel's plotting and graph tools to identify trends and patterns in machine failure and maintenance costs. Qualitative data from structured questionnaires and in-depth interviews were analyzed thematically to extract key themes related to digital skill utilization and workforce perceptions. The integration of both quantitative and qualitative analyses provided a comprehensive understanding of the factors contributing to the decline in productivity. Excel software facilitated the quantitative analysis of the gathered data, ensuring detailed visualization and effective interpretation of the results.

2.2.3 Application of regression model

Data collected on the causes of downtime and financial performance from the company's annual reports were subjected to multiple linear regression analysis using statistical software. The estimated coefficients will provide insights into the impact of each factor on downtime. It is acknowledged that external factors may influence the model, and the study is constrained by the availability and accuracy of historical data. The study adhered to ethical standards in data collection and analysis, ensuring confidentiality and integrity. The general form of a multiple linear regression model is given by [26,29,30]:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\ldots+\beta_nX_n+\epsilon \qquad (1)$$

Where:
Y: total downtime in the body assembly line, *Xi:* percentage of response related to the identified causes *(n).*

To make it explicit, the equation is expressed as:

$$Y=\beta_0+\beta_1\times MD+\beta_2\times MFM+\ldots+\beta_{10}\times FC+\epsilon \qquad (2)$$

Where:
$\beta_0,\beta_1\ldots,\beta_{10}$ = coefficient to be estimated which includes: *MD* = market dynamics, *MI* = management issues, *MFM* = machine failure/maintenance cost, *SCD* = supply chain disruptions, *TO* = technological obsolescence, *LR* = labor relations, *RC* = regulatory challenges, *QI* = quality issues, *PI* = political instability, and *FC* = financial challenges and ϵ = error term. This methodology outlines the systematic process to develop a model equation for optimizing the automotive manufacturing system productivity. It provides a structured approach to analyze and interpret the identified causes of downtime

2.2.4 Structural equation model (SEM)

Another recommended model for this research is structural equation model (SEM), which aims to examine the relationship between non-financial firm performance (NFPMS), lean manufacturing, and the moderating variable of lean culture in the context of the automotive company sourced data. The relationship between proxy of NFPMS and lean manufacturing including the moderating variable of lean culture will be established using SEM modified from Odeyinka et al. [31]; Ben et al. [32]; Adedokun and Egbelakin [33]; Odeyinka and Adegoke [34].

Relationship between lean culture, empowerment, and training and development is given by:

$$LC= \beta_0+\beta_1 EMPT+\beta_2 TDT+\epsilon \quad (3)$$

This model focuses on how lean culture *(LC)* is influenced by two factors: empowerment *(EMPT)* and training and development *(TDT)*. The second model (equation 4) examines how product quality *(PQTY)* is affected by empowerment *(EMPT),* training and development *(TDT),* and lean culture *(LC).* This relationship is expressed as:

$$PQTY= \beta_0+\beta_1 EMPT+\beta_2 TDT+\beta_3 LC+\epsilon \quad (4)$$

These models will help in understanding the direct and indirect effects of empowerment, training and development, and lean culture on product quality, thereby providing insights into the factors contributing to the decline in non-financial firm performance in the automotive industry. The structured questionnaires gather data, drawing on instrumentation from previous empirical studies.

The research focuses on staff size of 433 out of 794. Proportionate sampling distributes 208 questionnaires across three senatorial districts, and 204 valid responses are obtained. Utilizing the Taro-Yamane sampling technique, the study employs the structural equation model (SEM) for analyzing lean culture's impact on the relationship between lean manufacturing and non-financial firms' performance in Enugu state. STATA 13.0 facilitates the SEM analysis. The Taro-Yamane Sample model is given by:

$$n = N/ (1+N (e)^2) \quad (5)$$

Where: n = signifies the sample, N = signifies population and e = signifies margin error. MATLAB software was applied to run the models

2.2.5 Validation of the applied models

After sourcing data from the related sources, the data was also analyzed using both SEM and regression model. Afterward, to measure the goodness of fit for these models, two key functions was employed, which includes: root mean square error (RMSE) for the regression model and the coefficient of determination (R^2) for the SEM.

Regression Model Validation with RMSE

The goodness of fit for the regression model was assessed using the RMSE. RMSE measures the average magnitude of the errors between predicted and observed values, providing insight into the accuracy of the model's predictions Chicco et al. [30]. A lower RMSE value indicates a better fit. The formula for RMSE is:

$$RMSE =\sqrt{\frac{1}{n}\sum_{i=1}^{n}(yi - \hat{y}i)^2} \quad (6)$$

Where: yi are the observed values, $\hat{y}i$ are the predicted values n is the total number of observations.

SEM Validation with Coefficient of Determination (R^2)

The coefficient of determination (R^2) was used to evaluate the SEM. R^2 measures the proportion of variance in the dependent variable that is predictable from the independent variables, indicating how well the model explains the observed data [32,33]. The value of R^2 ranges from 0 to 1, with higher values indicating a better fit [34]. The formula for R^2 is:

$$R^2 = \frac{1-\sum_{i=1}^{n}(yi-\hat{y}i)2}{\sum_{i=1}^{n}(yi-\bar{y}i)2} \quad (7)$$

Where: $\hat{y}i$ are the predicted values, yi are the observed values, and $\bar{y}i$ is the mean of the observed values. By employing these measures, we were able to validate the models effectively, ensuring the reliability and accuracy of our findings. The use of MATLAB software facilitated the complex computations and graphical representations necessary for this analysis.

2.2.6 Recommendation of Strategic Maintenance

Based on the findings, recommendations, and strategies were formulated to address the identified root causes [26,29]. Strategies included suggestions for optimizing machine maintenance processes, integrating digital skills into manufacturing practices, and potentially adopting Lean manufacturing technologies such Ishikawa diagram and eight deadly wastes common to the manufacturing and service rendering industry, which identifies the root causes of any declining factors of the company [22,25]. The recommendations were informed by industry best practices and tailored to the specific challenges identified from the case study automotive company in Nigeria. The aim was to provide actionable insights that can contribute to the revitalization of productivity and sustainability in the company.

3. RESULTS AND DISCUSSION

In this section, we present and analyze the findings derived from the data collected and processed using the modified SEM and regression model. The analysis was conducted using MATLAB software, which facilitated the detailed examination and validation of the models. The focus will be on interpreting the results from both quantitative and qualitative perspectives to provide a comprehensive understanding of the factors influencing the productivity decline in the automotive company. The outcomes are discussed in relation to their implications for lean manufacturing practices and non-financial firm performance.

3.1 Data Collection Analysis

Fig. 2 presents the response data from the questionnaires, highlighted several potential factors contributing to the decline in manufacturing productivity at the automotive industry. Political instability emerged as the most significant factor (20%), while machine failure and maintenance costs also posed substantial concerns (18%). Financial challenges (15%) and management issues (12%) further impacted productivity. Quality issues (9%), labor relations (10%), market dynamics (8%), supply chain disruptions (7%), regulatory challenges (6%), and technological obsolescence (5%) were also noted. These insights suggest that a comprehensive approach addressing both internal and external factors is crucial for revitalizing the automotive assembly industry's productivity [11,12].

Fig. 3 presents the different shareholders of the company. The result obtained indicates that shift in shareholder distribution and the exit of Daimler-Benz, which held a 40% share, significantly impacted the company's productivity. Also, the change increased government control, potentially leading to bureaucratic delays and inefficiencies. Financial stability also suffered, as Daimler-Benz's departure deprived the company of essential capital and expertise. Technological progress slowed, risking obsolescence due to the lack of advanced industry knowledge. Market adaptability weakened, potentially reducing market share and revenue. Management issues arose, with difficulties in strategic alignment among remaining shareholders. Addressing these challenges requires strategic initiatives and financial restructuring [17].

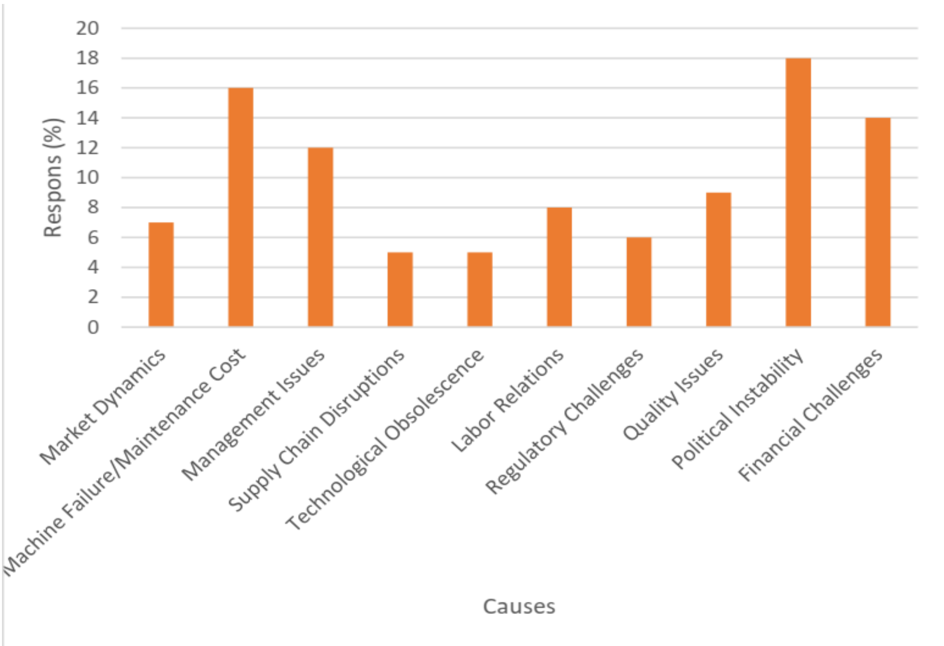

Fig. 2. Response on possible factors that caused the company collapse
Source: Questionary

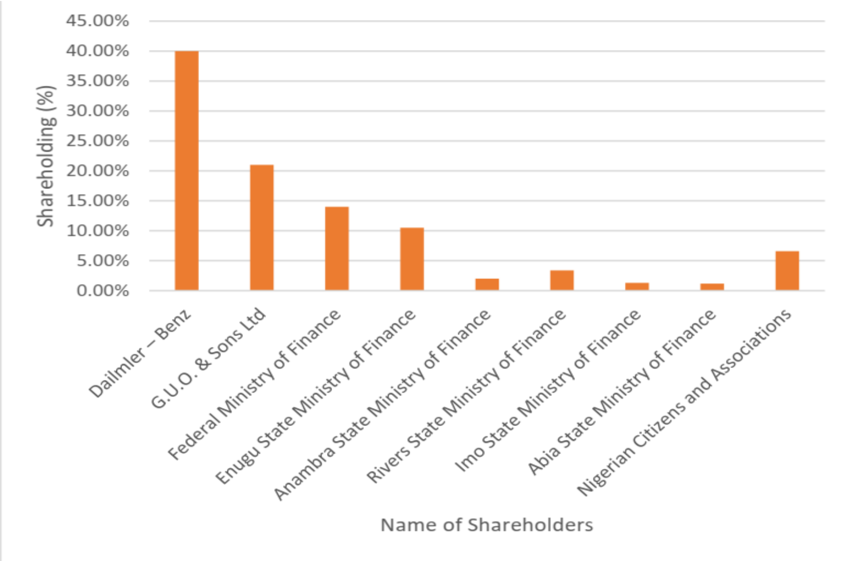

Fig 3. Shareholder distribution and ownership percentages
Source: Company's Journal and Library

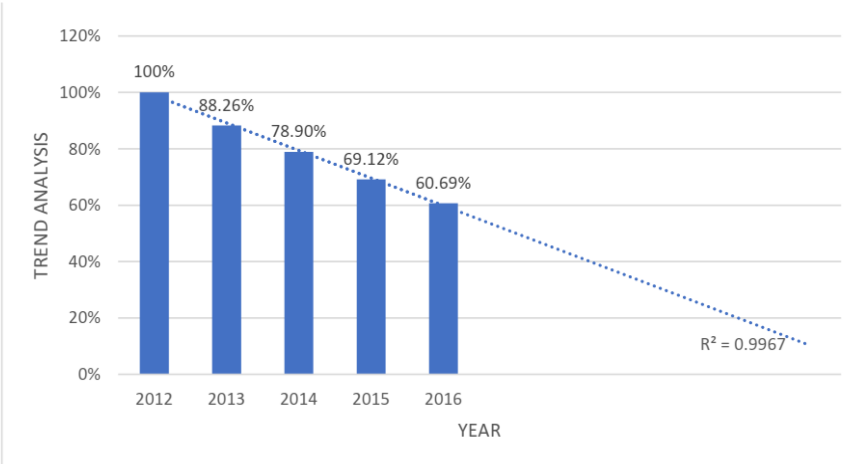

Fig 4. The Company's financial performance from 2012-2016
Source: Company's Financial Report Department

Fig. 4 represents the trend percentage analysis of the company's financial performance from 2012 -2016. From the observation, a downward trend from 2012-2016 was observed, which indicate reasonable profit of about 100% for 2012, but in other years like in 2013, a downward trend reduction in productivity shows 88.26%, 78.90% for 2014 69.12% for 2015 and 60.69% for 2016. This result signifies that the financial performance was not healthy. The reduction in the net-income also resulted to the declined productivity of the company [26,31].

Fig. 5 shows a summary of downtime in the company's body and chassis assembly lines from 2012 to 2016. It was observed that chassis line machine experienced lower downtime compare to the body assembly line maybe due the body assembly working components are affected with complexity of operations, higher usage, maintenance challenges, environmental factors such as exposure to chemicals, dust, and temperature variations. Although the downtime decreased from 900 hours in 2012 to 720 hours in 2016 for the body assembly line, and from 430 hours to 340 hours for the chassis assembly line, this reduction is attributed to a decline in manufacturing time due to internal and external factors. Reduced production time, rather than improved efficiency, led to lower downtime, negatively impacting the company's manufacturing output and overall productivity. This trend reflects underlying challenges in maintaining optimal operational capacity.

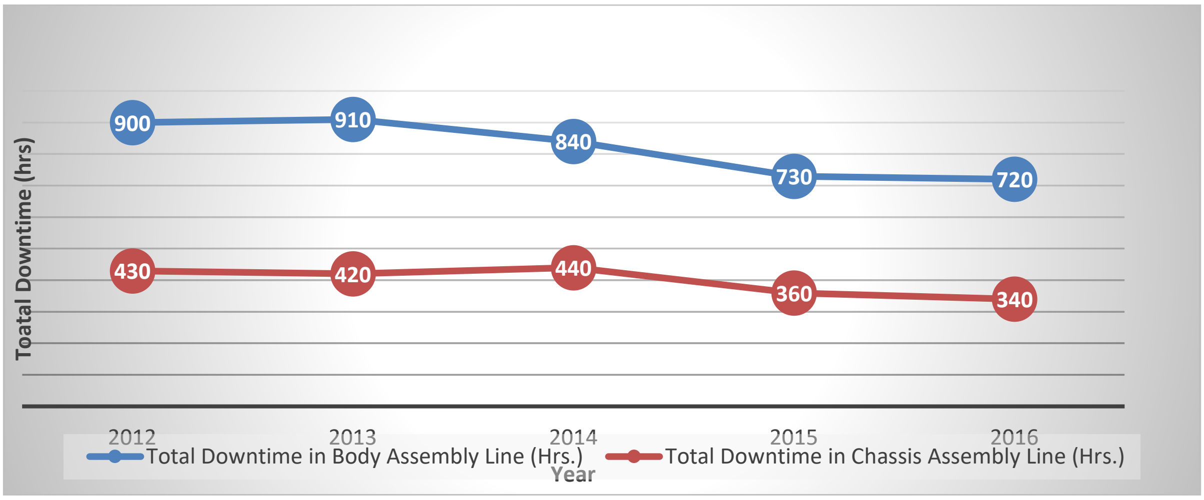

Fig. 5. The company's total machine downtime trend
Source: Company's Maintenance Department

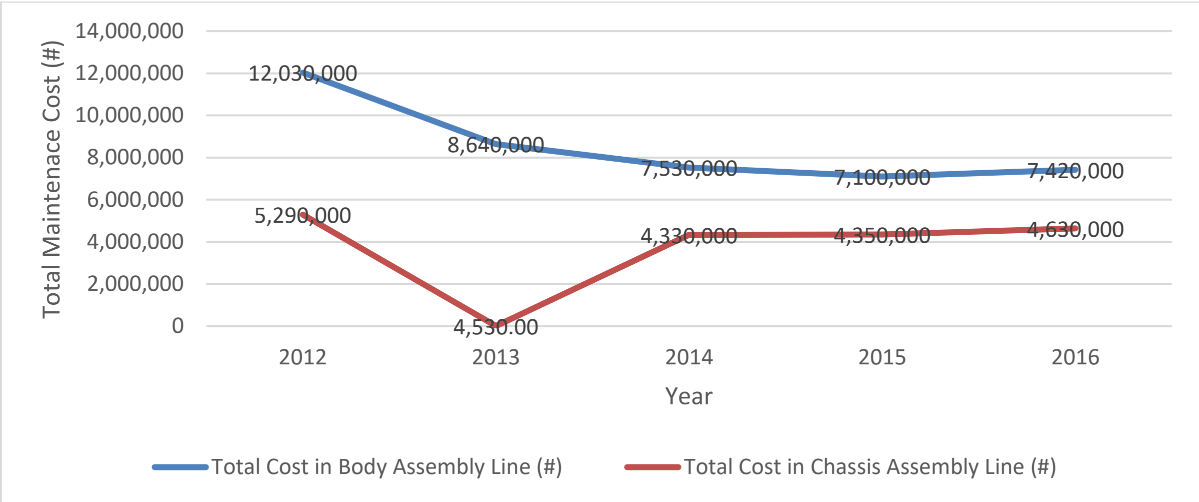

Fig. 6. The Company's annual machine downtime maintenance cost trend
Source: Company's Financial and procurement Department Diary

The total cost of downtime in the body assembly line consistently exceeded that of the chassis assembly line from 2012 to 2016. The body assembly line's costs decreased significantly from ₦12,030,000 in 2012 to ₦7,100,000 in 2015, before a slight increase to ₦7,420,000 in 2016. In contrast, the chassis assembly line's costs were lower and more stable, ranging from ₦5,290,000 in 2012 to ₦4,630,000 in 2016. This disparity highlights the higher complexity and maintenance demands of the body assembly processes compared to the chassis assembly operations.

Fig. 7 presents a survey on staff knowledge and usage of management tools. project management tools (PMT), such as Trello and Asana, were frequently used, indicating staff familiarity. communication and collaboration tools (CCT), like slack and zoom, were also well-utilized. However, document collaboration tools (DCT) and performance management systems (PMS) were less familiar, with many staff members rarely or never using them. Lean manufacturing technology (LMT), customer relationship management software (CRM), and time tracking software (TTS) had moderate usage. These results suggest a need for targeted training to improve familiarity with less-used tools [5-8].

3.2 Recommendation of Strategic Maintenance

After critical review of root causes of the company's collapse in automotive assembly sector of the company, which machine failure is one of the key causes having 16% cause slight above the highest factor which is political factor (see Fig. 2), some machine and managerial improvement and startup strategies were recommended in Table 5 – 7 and Fig. 7, utilizing lean manufacturing techniques.

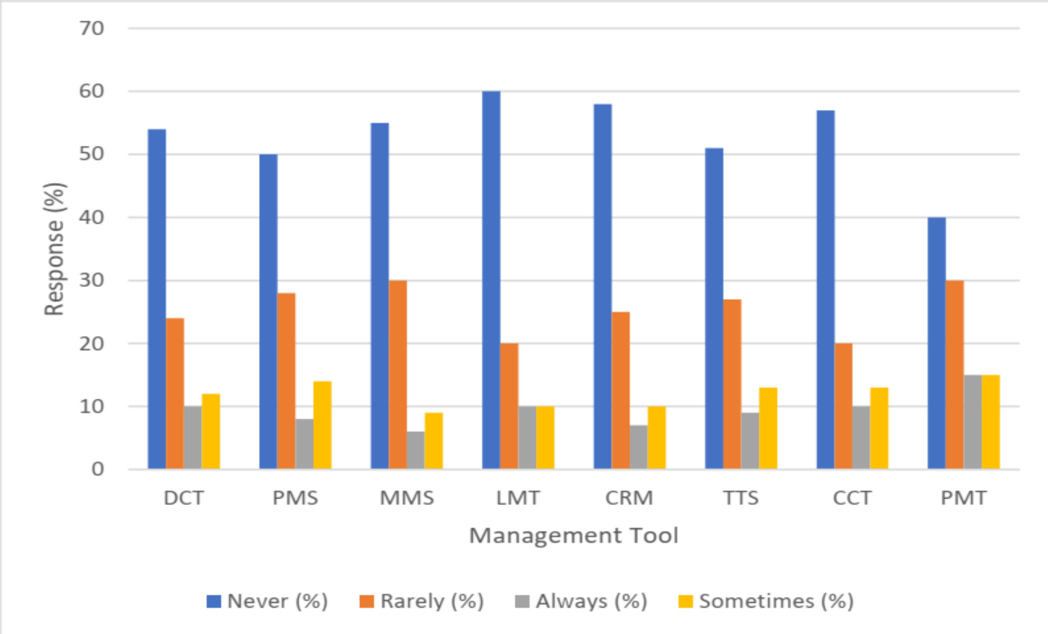

Fig. 7. Management tools knowledge response from the staff
Source: Questionary and File Survey

Table 5. Machine Maintenance and Performance Improvement Strategies for Automotive Body Assembly Line

Machine	Persistent Problem	Corrective action	Preventive action
Welding Robot	Overheating	Check and clean cooling systems regularly.	Implement a regular maintenance schedule for cooling systems.
Metal Stamping Press	Jamming	Inspect and lubricate moving parts regularly	Implement a preventive maintenance plan for moving parts
Paint Application System	Uneven Coating	Calibrate spray nozzles and pressure settings	Conduct regular checks and calibration of the system.
Body Inspection Station	Sensor Malfunction	Replace or recalibrate malfunctioning sensors	Regularly inspect and calibrate sensors as part of preventive maintenance.
Assembly Line Robots	Programming Errors	Debug and correct the robot's programming	Implement a process for thorough programming reviews and testing.
Body Coating Booth	Overspray	Adjust and maintain spray gun settings	Regularly inspect and clean spray nozzles to prevent overspray.
Laser Cutting Machine	Focus Drift	Recalibrate the laser focus	Implement routine checks and recalibration for laser focus

Table 6. Machine maintenance and performance improvement strategies for automotive chassis assembly line

Machine	Persistent Problem	Corrective action	Preventive action
Chassis Welding Robot	Welding Defects	Inspect and adjust welding parameters.	Implement regular inspections and maintenance of welding equipment.
Chassis Rolling Machine	Misalignment	Align and calibrate rolling components.	Schedule routine alignment checks and adjustments.
Chassis Assembly Conveyor	Conveyor Jams	Clear jams promptly and inspect conveyor.	Implement a preventive maintenance plan for conveyor components.
Chassis Frame Fixture	Fixturing Issues	Inspect and correct fixture alignment.	Regularly check and align fixtures during preventive maintenance
Suspension System Tester	Sensor Calibration	Calibrate sensors and replace if necessary.	Implement a regular calibration schedule for sensors.
Chassis Alignment Machine	Alignment Drift	Realign the machine components.	Conduct routine checks and alignments as part of preventive maintenance.
Chassis Quality Control	Inspection Failures	Investigate and address inspection failures.	Enhance training for operators and conduct regular equipment checks.
Chassis Welding Robot	Electrical Issues	Inspect and repair electrical components.	Implement routine electrical system inspections and maintenance.
Chassis Rolling Machine	Material Feed Issues	Adjust and maintain material feeding systems.	Regularly inspect and clean material feeding components.

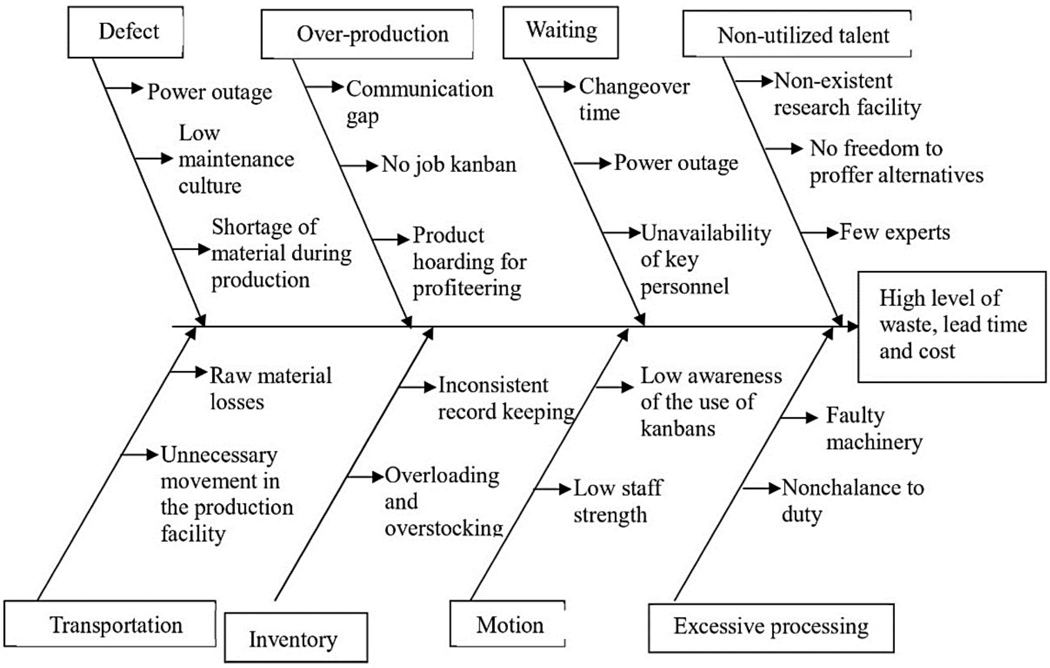

Fig. 7. Ishikawa diagram for system

Table 7. The eight deadly wastes of a typical manufacturing company and proposed remedies

[1] DEFECT	
Category/Inference	**Possible remedy**
Power Outage: i. Due to power outage during production. ii. Materials not completely processed were taken to next stage. iii inadequate technical know-how.	Standby plant or electrical generator with a supporting UPS/inverter in readiness for any production scheduled time; more training on the product development is required.
Low maintenance culture: i). Nozzles are operating at half-mast. ii)Longer production time per unit manufactured. iii. Tendency for defect occurrence is very high aging equipment.	Preventive maintenance culture should be imbibed to cost associated with reprocessing; replace equipment.
Shortage of Material: i). because there seemed to be no accurate knowledge on the availability of parts. ii). chaos erupted on sudden realization that some parts were in short supply.	More emphasis should be placed on accurate Stock keeping and Kaban should be included in the working process and also regularly updated to prevent information gap.
[2] OVER PRODUCTION	
Communication Gap: i). Because assumptions were made based on previous orders. ii). Because there was no use of Kanban. iii). Due to hopes of producing at low exchange rate for profits when the rate increases.	The product should be produced based on customer order and part service follow-up as important to obtain the mindset of the costumer, use of Kanban should be implemented to avoid over and under production.
No Kanban: i). No enforcement of kanban use leads to wrong output. ii). Stocking these unrequested products consumed space, and deformed some products.	Personnel should be assigned to information gathering, customer requests and feedback.
Product Hoarding: i). Overstay of goods in the warehouse was observed ii. A good amount of stocked product was recycled due to defect.	More focus should be on customer satisfaction than profiteering.
[3] WAITING	
Change Over Time: i. Lots of cleaning to be done before the next shift. ii. Changeover time is not standardized. iii. Supervisors are guilty of late coming and can't discipline their team. iv. Lackadaisical attitude to work.	Reduction in number of debris produce during production process; enforce regular cleaning schedules; introduce better ways of manufacturing the product.
Power Outage: i. Lost time created by generator fault. ii. Scarcity of diesel and administrative faults in the area of allocation towards purchase of diesel.	Arrangements geared towards to production process should be concrete; a set allocation for diesel and all prerequisite for steady power supply should be formalized and issued on time per production periods.
Unavailability of Personnel: i. To save cost, the company is understaffed. ii. Negligence and lateness to work.	The right amount of personnel will save time and cost; top management should install more discipline.
[4] NON-UTILIZED TALENTED AND SKILLED WORKERS	
i. Technical know-how in major production process such furnace heating cold milling was poor	Incentive should be awarded to personnel with brilliant Ideas; the right person for the job should be given the opportunity to work and trainings are

ii. Nepotism was evident iii. No freedom to express views iv. iv. Little or no training sessions	imperative.
[5] TRANSPORTATION	
Erratic movements: i. Shortage of staff leads to erratic movement in the facility. ii. Fire brigade approach led to rush and consequent spill of material. iii. low level safety procedure and no cleaning personnel.	Operations and safety meetings should be mandator before every process; materials should be at their needed locations before production begins to avoid rush; forklifts and other mechanical equipment should be maintained to prevent loss of material through accident or machine failure.
[6] INVENTORY	
Inconsistent Record Keeping: i. No interest in record keeping. ii. Material spill, defect, and re-do operations are not properly accounted for.	Company auditing should be a culture; a computerized database should be used to avoid relapse which could result from manual or paper recording.
Overloading/Overstocking: i. Anticipated request for product cause overstocking. ii. Fear of being stocked out and trying to meet urgent demand. iii. Due to stocks held for quality inspection to avoid sending defective products to the customer.	Produce based on order; Inform customers on waiting period before delivery; keep smaller stock.
[7] MOTION	
Low Awareness of Kanban: i. No training ii. no team work and no written job instruction.	Lean training on usage and importance of kanban
Low Staff Strength: i. Trying to save cost due to salary payments. ii. Less hands for different attention needing sectors of the manufacturing process.	Employ required number of staff to many important positions
[8] MACHINE MISMANAGEMENT	
Faulty Machinery: i Machine malfunction caused a good number of wastages. ii. Trying to save cost hence managing aging equipment with lots of inefficiencies	Maintenance culture is prerequisite; buy new equipment.
Nonchalance to Duty: i. Individual overconfidence in the manufacturing process ii. Monotony.	More discipline; rotation of some staff to curb growth of monotonous tendencies.

Table 8. Regression model performance evaluation and SEM model performance evaluation

Regression Model Performance Evaluation			**The SEM Model Performance Evaluation**					
Observed Y	**Predicted Y**	**Squared Error**	**Variable**	**Obs.**	**Mean**	**SD**	**Min.**	**Max**
150	148.5	2.25	PQTY	204	2.6618	0.0126	1.5	4.0000
200	201.2	1.44	EMPT	204	3.1804	0.5053	2.2	4.6000
180	179.8	0.04	TDT	204	2.5089	0.5922	1.6667	4.0000
220	219.7	1.21	LC	204	2.4739	0.6796	1.6667	4.6667
250	251.4	2.56	-	-	-	-	-	-

Table 9. The SEM Model Matrix and Coefficient Values of the SEM Model

The SEM Model Matrix					**Coefficient Values of the SEM Model**		
	PQTY	**EMPT**	**TDT**	**LC**		**Model 1**	**Model 2**
PQTY	1.000				**LC** Coeff.	-0.0781	
EMPT	0.6676	1.0000			**EMTY** Coeff.	0.6038*	0.7939*
TDT	0.8338	0.5888	1.0000		**TDT** Coeff.	1.1331*	-0.2608*
LC	0.1649	0.4566	0.1203	1.0000	**Note:** *P< 0.01		

After investigating the root causes of production decline in the automotive assembling industry, strategic concepts were developed to address these issues. Tables 5 and 6 outline machine maintenance and performance improvement strategies, specifying common faults and their corrective and preventive measures for the body and chassis assembly lines. Fig. 7 displays an Ishikawa diagram, highlighting operational and managerial issues and trends to mitigate them. Table 7 presents strategies to tackle eight key manufacturing wastes—defects, overproduction, waiting, underutilized talent, transportation, inventory, motion, and machine mismanagement—aiming to enhance company management and production.

3.3 Validation of the Applied Model

The following tables present key statistical results from our study, highlighting the performance of the regression model and the SEM.

Tables 8 and 9 presents the regression model evaluation, observed and predicted values, which show low squared errors, indicating a good fit. Descriptive statistics from the SEM model reveal mean values and standard deviations for *PQTY, EMPT, TDT,* and *LC*. The SEM model matrix shows significant correlations among variables. The coefficients for *Model 1* and *Model 2* highlight the impact of *LC, EMPT,* and *TDT* on *PQTY*, with statistically significant results ($P<0.01$). This comprehensive analysis underscores the effectiveness of the models in explaining the relationships between the studied variables and their impact on production outcomes.

4. CONCLUSION

The study on automotive assembly company in Nigeria reveals that the company's productivity decline is significantly influenced by equipment failures, high maintenance costs, and changes in shareholder structure. The departure of Daimler-Benz and inadequate technological advancements have exacerbated the situation. The regression and SEM models provided insights into these issues, suggesting that financial restructuring and adopting modern technologies are critical for improving productivity. Emphasizing employee training and integrating digital skills can further enhance operational efficiency. This research offers valuable recommendations for mitigating productivity decline and fostering sustainable growth in the automotive industry.

CONSENT

As per international standards or university standards, Participants' written consent has been collected and preserved by the author(s).

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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