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Research Paper

Enhancing Sustainable Production Through Continuous Improvement: Evidence from Nigeria's Manufacturing Sector

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Abstract. The manufacturing industry in Nigeria has been the so-called cornerstone of economic development since the sector has continuously played a major role in providing jobs and industrial capital. However, there remain issues that impede its progress, including inefficient resource use, unstable regulatory systems, and the need to comply with international market requirements. Specifically, it examined the effect of employee engagement, process efficiency, and resource allocation on Nigeria's manufacturing sector. A survey research design was adopted, with a total population of 117 employees across five manufacturing firms. A total of 91 participants were administered a structured questionnaire. Data collected was analyzed using PLS-SEM. Findings revealed that employee engagement has the strongest effect on sustainable production ($\beta = 0.412$, $t = 6.250$, $p < 0.000$), followed by resource allocation ($\beta = 0.237$, $t = 3.610$, $p < 0.000$), and process efficiency ($\beta = 0.174$, $t = 2.877$, $p = 0.004$). It concluded that continuous improvement is significantly vital for sustainable production in the five sugar manufacturing firms studied in Nigeria. It is therefore recommended that management of these selected firms focus on developing unique resource allocation strategies, employee engagement, and process efficiency to ensure sustained workforce improvement, thereby achieving sustainable production outcomes.

Keywords: Continuous Improvement, Sustainable Production, Employee Engagement, Process Efficiency, Resource Allocation.

Introduction

The manufacturing industry in Nigeria has been the so-called cornerstone of economic development since the sector has continuously played a major role in providing jobs and industrial capital. However, there are still issues that impede its progress, such as wasteful resource use, unstable regulatory systems, and the need to comply with international market requirements. According to current empirical research, operational inefficiencies, which encompass the challenges faced in Nigerian factories, are often exacerbated by outdated technologies and disjointed supply chains, thereby reducing productivity and degrading environmental outcomes [1]. For example, a study of the energy-use habits of factories in Lagos found that the ratio of affordable operations was unreasonably high, so an estimated 40 per cent of overall expenses was attributable to waste management, creating economic and environmental costs [2]. Such challenges have prompted efforts to develop approaches that do not

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sacrifice long-term competitiveness without being environmentally conscious, given trends in international trade that increasingly favour businesses that prioritize the environment [3].

Against this backdrop, empirical studies have shown that there are incremental changes in the operation of reforms that can produce the desired results. A 2022 case study of textile manufacturers in Kano has shown that the adoption of data-driven decision-making means can reduce material waste by 22 per cent in half a year, and at the same time, improve the product quality [4]. Analyses of cross-sector similarly recorded that companies with a proactive approach to maintenance recorded 15-30 per cent less downtime, which, in turn, is directly proportional to increased annual output [5]. Such outcomes emphasize the need to have adaptive frameworks, which can fit into the reality of the local infrastructures. As an instance, the exchange of knowledge between academia and the industry related to the optimization of the production lines has been made possible through collaborative efforts by academia and industry, as seen in the case of the University of Ibadan and car parts manufacturers [6]. These attempts point to the opportunity for context-based discoveries to reduce systemic inefficiencies.

The changing discussion on industrial resilience in Nigeria also raises a further problem on the importance of stakeholder involvement in systems change. The incentives have been provided by the regulatory policies, including those issued by the National Environmental Standards and Regulations Enforcement Agency (NESREA), where manufacturers are pushed towards using cleaner technology, but the level of compliance is irregular across the regions [7]. According to the research, companies that joined the sustainability certification programs had their export opportunities grow by 12%, which represents the changing consumer preferences [8]. Furthermore, longitudinal research monitoring 50 medium-sized companies from 2018 to 2023 found that companies that incorporated iterative feedback loops into their operations recovered from supply chain disruptions more quickly [9]. These results can be explained by broader trends in industrial policy, whereby adaptive strategies are increasingly important for navigating turbulent markets [10]. Together, these implications support the need for a holistic approach that considers economic objectives alongside ecological and social needs.

As much as employee engagement is needed in organizational productivity, it is inadvertently self-destructive when set against the short-term measures of performance. Interested employees tend to focus on productivity and effectiveness to achieve organizational goals at the expense of environmental factors. For example, Graham et al. [11] emphasize that increased manufacturing activity is associated with greater resource use because employees are no longer oriented towards reducing waste but towards maximizing output. Likewise, Amjad et al. [12] discovered that productivity-focused engagement programs and similar programs resulting in practices containing over-production or power-intensive production streams can contribute to increasing the ecological footprint. This is further aggravated by the fact that sustainable practices lack a training program; research conducted by Sharma et al. [13] found that 68 per cent of workers in high-engagement industries did not know the concept of the circular economy, which continues to propagate linear production models. Unless sustainability is part of engagement approaches, organizations may find themselves having developed business cultures that ignore environmental care in favor of operational effectiveness [14],[15].

Industrial optimization, which has process efficiency as one of its pillars, has oftentimes come into conflict with sustainable production when sought without ecological protection. The cost and waste reduction methods by lean manufacturing are a deliberate move that might occur at the expense of

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preserving resources. To illustrate this point, Ugarte et. Al. [16] established that industries that have implemented just-in-time production frameworks augmented their carbon footprint as a result of recurring, small-scale supply of goods that depend on fossil fuels. Furthermore, Anyanwu and Kur [17] are of the view that automation, which comes as a result of efficiency concerns, can result in excess consumption of energy in segments that rely on non-renewable sources of power. Davis Meike et al. [18] found, in a case study of the automotive sector, that robotic assembly lines optimized for high efficiency used 22 percent more energy than semi-automated assembly lines that had already achieved higher material waste efficiency. These results highlight the efficiency paradox: approaches that make operations more efficient need not address systemic environmental effects, which require measuring productivity and sustainability [16], [17].

Decisions made concerning the allocation of resources through prioritization of the immediate economic benefits of the current resources are likely to hinder production in the long run because they de-prioritize the investments by the organization in the environment in the long term. Individually, as an example, Pehl et al. [19] discovered that the companies that budgeted themselves to use fossil fuel-based machinery instead of renewable energy infrastructure paid less upfront prices, but the lifetime emissions were 34 percent higher. On the same note, Periyasamy [20] found that companies in the textile industry used the money allocated to water-recycling systems for marketing, thus further increasing water shortage in their production areas. This short-termism is supported by the pressure of shareholders to generate quarterly profits, according to Xue et al. [21], they also associated underinvestment in sustainable research and development with pressure from investor demands to realize instant profits. This misuse further fosters the use of non-renewable resources, and it slows the implementation of cleaner technologies, which provide systemic obstacles towards the implementation of net-zero targets [19],[20].

So specifically, the objectives of the study will include: to determine the effect of employee engagement on sustainable production, to investigate the influence of process efficiency on sustainable production, and to examine the influence of resource allocation on sustainable production.

1. Literature Review

1.1. Conceptual Review

1.1.1. Concept of Continuous Improvement

Continuous Improvement (CI) is an analytic, strategic framework that has been formulated to help in improving organizational products, services, and processes using both incremental innovations and breakthrough innovations. Based on the modern concepts related to Kaizen and Lean management, CI has put the engagement of the employees as a priority, iterative problem-solving, and decision-making based on data as the tools in the systematic elimination of inefficiencies [22]. Corporations that embrace the use of CI develop a culture where feedback loops and cross-functioning promote endless forwardness, hence organizational agility in dynamically changing markets [23]. One of the most striking examples of it is the incorporation of digital technologies, such as artificial intelligence and the Internet of Things, which expands the scope of CI and allows real-time analysis that reveals the

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bottleneck and can be optimized to make the workflow as efficient as possible [24]. Such a philosophic approach is not restricted to the manufacturing industry, but extends to other areas of life like healthcare and education, essentially projecting Customer-centric results and system resilience forward [25]. However, the success of CI depends on dedicated leadership and the organizational desire to learn to make learning a part of the organization, as one-off projects often lack the capacity to maintain momentum [26].

The researchers insist that the effectiveness of CI is magnified in a situation where CI is aligned with strategic goals such that the incremental gains should yield beneficial results to the overall objectives of the organization instead of individual gains [27]. The psychological safety is also central because the employees should have the sense of empowerment to suggest changes even without the fear of being reprimanded [28]. One such well-known production system at Toyota is an example of CI scalability; in this case, small innovations that are employee-initiated can reduce waste and increase the quality levels, respectively [29]. Nonetheless, critics note that depending on incrementalism too much can be counterproductive because a radical transformation of at least some kind can be necessary to face a disruptive challenge, contravening the gradual ethos of CI [23]. As a result, the use of CI is necessary, but the stability and agility between these two concepts must be balanced to cope with the ever-changing dynamics of organizations being more intricate.

1.1.2. Concept of Sustainable Production

Sustainable Production (SP) is defined as the use of processes to produce goods and services that reduce the harm to the environment and conserve resources, as well as maintain social equity. The idea behind SP is based on the principles of the circular economy and cradle-to-grave design, which are all aimed at separating the growth of the economy from the ecological damage and focusing on using renewable materials and energy efficiency [30]. An example that is relevant is the adoption of closed-loop systems by industries, when the wastes become reused into inputs, thus avoiding the use of virgin resources and stemming pollution [31]. Regulatory policies, such as the Green Deal of the EU, also reinforce SP, as it obliges the carrying out of lifecycle assessment and carbon neutrality goals [32]. Although there is an ethical rationale behind it, SP has challenges on the implementation front, such as huge initial expenses and any build on technology constraints, especially in emerging economies [33].

The social aspect of SP predicts equitable labour practices and civic prosperity, making sure that the manufacturing set-ups avoid exploitation of the workforce and marginalized minority groups [34]. Fair-trade certifications have encouraged ethical sourcing; however, opponents state that tactical approaches often do not have mechanisms to enforce them [35]. Other innovations like biomimicry and green chemistry continue progressing SP as they mimic nature and come up with products that are non-toxic and biodegradable [36]. However, such a radical change in consumer behaviour and corporate governance is the key to real sustainability since the technocentric approaches would never be sufficient to combat overconsumption [37]. This means that the holistic vision of SP requires interdisciplinary cooperation that integrates policy, technology, and cultural change to balance economic feasibility with planetary limits [38].

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1.1.3. Effect of Continuous Improvement on Sustainable Production

Continuous improvement (CI) can be seen as a part of the sustainable production that incorporates the small improvements to enhance resource efficiency and reduce waste. As an example, Vinodh et al. [39] argue that both digital and lean practice creation of CI is the basis of long-term sustainability in Industry 4.0 settings. The firms facilitate the process of repeated improvements in the process flows and material utilization by turning to more frequent interventions to integrate routines in operation, which become consistent with ecological outcomes. Cunha et al. [40] offer empirical data about the fact that the performance-measurement systems in the CI settings are critical in terms of maintaining gains in the long run. Therefore, CI is the process according to which firms transform into efficiency and sustainability and integrate environmental stewardship into the production systems in the long run.

The organizational culture, support of the leadership, and compatibility with the sustainability strategy are the determinants of the sustainability of the CI-driven production improvements. As Rodriguez-Gamez et al. [41] show, a framework of socio-environmental sustainability and effective processes must be shifted using a value-chain framework that uses the principles of CI. It is embedded into CI within strategic sustainability initiatives that will guarantee that the additions to the organization are tracked, institutionalized, and extended instead of turning out to be individual events. According to the conceptual literature, CI should be perceived as an organizational ability that combines human, technological, and process levels to attain the sustainability of the impact [42]. In that regard, CI not only enables operational change but also increases operational production systems' resiliency in the face of changing environmental and market conditions. To conclude, continuous improvement proves to be a strategic facilitator of sustainability in production in lieu of an operational strategy.

1.1.4. Effect of Employee Engagement on Sustainable Production

Work engagement has a great impact on sustainable output through the creation of a workforce that is supportive of environmental and social goals. The highly engaged workers usually have increased discretionary effort, innovativeness, and responsibility, which translate into active offerings towards the sustainability programs- including waste minimization and energy conservation [43]. Empirical studies have shown that organizations that have engaged employees tend to embrace sustainable practices in their normal operation of the firm since individuals identify with organizational objectives and thus improve long-term ecological and economic performance [41]. As an illustration, research indicates that a high engagement rate is associated with better performance on the principles of the circular economy and taking part in recycling programs [44]. In addition, motivated employees are more likely to promote sustainable practices within their teams, thereby fostering a culture of continuous improvement that reduces resource consumption and environmental impact [41]. The above results highlight the critical importance of employee engagement in entrenching sustainability in organizational.

DNA that will spearhead concerted activities towards the achievement of sustainable production goals [43].

Thus, we propose the first hypothesis as follows:

H1: *Employee Engagement has a positive influence on sustainable production*

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1.1.5. Effect of Process Efficiency on Sustainable Production

The efficiency of processes is one of the foundations of sustainable production, as the usage of various resources is minimal, and the quality of output is maximized. Indicatively, a systematic review has found that lean manufacturing methods such as continuous improvement programs always have good impacts on eco-efficiency through decreased energy usage, material utilization, and non-productive outputs [45]. Lean-green integration of production processes has been shown to reduce carbon footprints and waste generation across a variety of manufacturing settings [46]. Through process improvement, companies can go on to closed-loop systems and use by-products, thus reducing the contributions to landfills and enhancing the concept of circularity. As a result, organizations will gain cost and efficiency advantages as they satisfy regulatory and consumer requirements of environmentally friendly and competitive performance, and locate process efficiency as a twofold driver of economic and environmental fortitude.

Thus, we propose the second hypothesis as follows:

H2: *Process Efficiency has a positive influence on sustainable production*

1.1.6. Effect of Resource Allocation on Sustainable Production

Sustainable production also largely depends on the strategic allocation of resources, as it ensures that the materials, labour, and energy used are matched to economic and ecological outcomes. It has been shown that when investments in renewable energy sources and energy-efficient technologies are optimized, the magnitude of environmental returns is significant and improves productivity [47]. For example, an analysis of the Chinese digital economy found that a better allocation of resources, enabled by green innovation, led to factor efficiency across 257 cities [48]. Additionally, opportunities to make decisions that enable local units to distribute resources in a more contextually robust manner enhance system resilience and sustainability [49]. Accordingly, resource allocation aligned with sustainability KPIs helps mitigate lifecycle risks, minimize lifecycle impacts, and provide the company with a competitive advantage in modern eco-conscious markets. It can be used to achieve sustainable production models, having been applied in conventional production, and this will be facilitated by effective strategic resource allocation [47].

Thus, we propose the third hypothesis as follows:

H3: *Resource allocation has a positive influence on sustainable production*

1.2. Theoretical Review

1.2.1. Kaizen Theory

The continuous improvement program popularized in 1986 by Masaaki Imai is known as kaizen, which focuses on employee-led, incremental changes to improve efficiency and quality and reduce waste. It was based on the Japanese post-war manufacturing, and it uses the Plan-Do-Check-Act (PDCA) cycle of iteration of problems and sustainability [50]. The theory presumes that the employees are encouraged to give ideas, the management promotes teamwork and that gradual changes are more easily sustainable than radical changes [51]. Critics mention, though, that Kaizen is too focused on incremental

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improvement and, as such, might suffocate radical innovation, especially in fast-changing sectors, and its success is contingent on supporting organizations having an enabling culture [52],[53]. This may be curtailed in developing economies like Nigeria that have structural constraints that may inhibit its effect, such as poor communication and instability in policy.

Irrespective of such shortcomings, Kaizen can still be used in terms of sustainable production in the manufacturing sector in Nigeria. Through the use of fewer wasted resources and the increase in operational efficiency, the companies that implement Kaizen have achieved a decrease in the number of defects and better environmental performance [54]. The evidence of its flexibility to the emerging economies is provided by similar applications in Ghana and India, but workforce training and management assistance are necessary to achieve success [53]. Since Nigeria is facing a problem of resource constraints, the low-cost high-impact model created by Kaizen is in line with the industrialization objective of the country, making it a feasible tool of sustainable production when combined with policy interventions [55].

1.3. Empirical Review

The article is a bibliometric analysis and literature review by Sesar [56] called The Relationship Between Continuous Improvement and Sustainable Performance: Bibliometric Analysis and Literature Review. The study searched 23 articles indexed in Scopus and related to the years 2018-2022 that directly covered two topics the continuous improvement (CI) and sustainability. The results show that CI practices are vital to the attainment of sustainable objectives of firms since they promote gradual enhancements in social, environmental, and economic performance. The conclusion of the review is that CI is a viable and successful method for organizations that want to achieve sustainability goals, but more research needs to be conducted empirically to explain the ways that CI is connected with sustainability.

Sakib et al., [57] introduced a work on Continuous improvement using Lean Six Sigma: a systematized literature review and bibliometric analysis. This review critically examined 1,992 articles published between 2001 and April 2024 and conducted an advanced systematic review with the help of a set of bibliometric tools, including RStudio, Biblioshiny, and VOSviewer. The paper established that LSS is a highly effective tool for increasing efficiency, minimizing quality and cost, and thereby leading to continuous improvement and sustainable production in any given industry. Recent trends identified in the review include the integration of digital tools into LSS to sustain the sustainability process. The authors concluded that LSS offers a robust system for implementing continuous improvement and sustainability, and identified new research opportunities in the ITisation of LSS practices. The thematic content of the article in question is a review of the use and effectiveness of lean manufacturing strategies in the industrial and service industries

The article is titled, A Review on the Implementation and Effectiveness of Lean Manufacturing Strategies on Industrial and Service Sectors which is being done by Gupta et al., [58]. This systematic review synthesized literature from the last five years on the application of Lean manufacturing in industry and the service sector. The research strategy was based on an extensive literature search and a bibliometric analysis to evaluate the effectiveness of Lean in reducing waste, improving productivity, and enhancing sustainability. The results prove the hypothesis that the implementation of Lean manufacturing, in particular, combined with other methodologies like Six Sigma and digital technologies, brings a great

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deal of improvement in efficiency and sustainability of the working process. The review concludes that, alongside Industry 4.0 and sustainability interventions, Lean may be used to improve the societal, economic, and environmental pillars of sustainable production.

1.4. Conceptual Framework

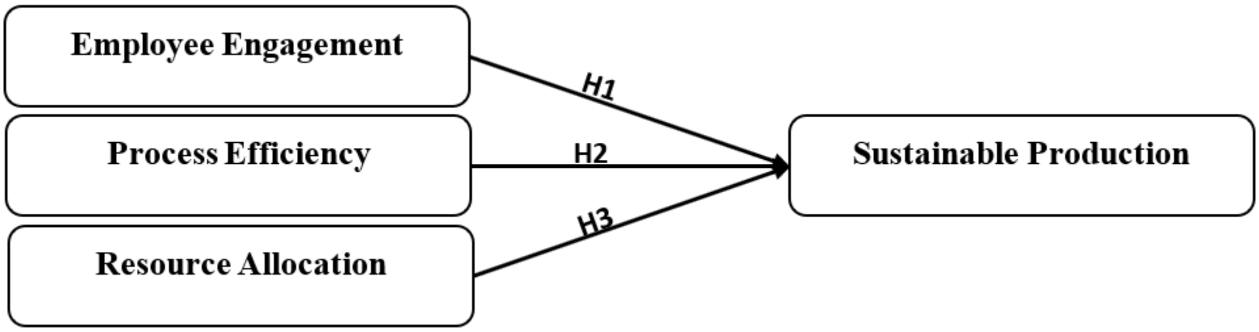

Figure 1: Conceptual model showing hypothesized relationships between continuous improvement dimensions and sustainable production

Source: Researchers' Design, (2025)

2. Methodology

A descriptive survey study design was employed in this research to provide empirical evidence and depict the research phenomena. The population of interest was the employees of five high-ranking sugar production firms in Nigeria: Dangote Sugar Refinery, Golden Sugar Company, Flour Mills Sugar Company, Sunti Golden Sugar Company, and Savannah Sugar Company. These companies were carefully selected because they are key players in the Nigerian sugar sector, distinguished by the scale of their operations, economic contribution to Nigeria, and history of large-scale production. They were selected to facilitate the generalizability of results to companies characterized by heterogeneous operations and strategic significance.

To achieve proportional representation across the company hierarchy, proportionate stratified random sampling was employed. A total of 115 questionnaires were distributed (23 employees from each of the five companies). However, only 91 usable responses were received, representing a 79.1% response rate. The reduction from 115 to 91 occurred due to incomplete questionnaires (14 responses) and non-responses (10 responses). The final sample of 91 respondents was deemed adequate based on the minimum sample size requirements for PLS-SEM analysis.

A standardized questionnaire was used to collect data. Construct validity was established through pilot testing and expert screening, and internal consistency of the instrument was assessed using Cronbach's alpha. Structural Equation Modelling (SEM) was used in analyzing data to examine the associations between the independent and dependent variables and the model fit and path significance as a whole.

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2.1. Model Specification

Sustainable production is the dependent variable in this study report, whereas continuous improvement is the independent variable. Since structural equation modelling (SEM) will be employed in the report, the following model will be used:

SP = f(Employee Engagement [CC+ PGO] + Process Efficiency [StdP+ SO] + Resource Allocation [FRD+ OCU])

Where:

- SP = Sustainable Production
- CC = Collaborative Culture
- PGO = Personal Growth Opportunities
- StdP = Standardized Procedures
- SO = Streamlined Operations
- FRD = Flexible Resource Deployment
- OCU = Optimized Capacity Utilization

PLS-SEM was selected as the analytical technique for several reasons: the sample size of 91 falls within the acceptable range for PLS-SEM but may be considered modest for covariance-based SEM, the study is exploratory in nature, examining relationships in the Nigerian manufacturing context where limited prior research exists, the data exhibited non-normal distribution patterns as indicated by skewness and kurtosis values in Table 1, and PLS-SEM is robust to violations of normality assumptions and suitable for complex models with multiple constructs [59].

3. Results

3.1. Response Rate

A questionnaire was used in this investigation to obtain the needed data. A total of 91 responses were received, representing 91.2% of the target sample size; an additional 8 responses were required to meet the projected sample size. As a result, the legitimate replies collected ended up serving as the dataset for this study.

3.2. Descriptive Analysis of Responses and Normality Test

The table below presents descriptive statistics for the items used in the study. The item codes are E1, E2 for Employee Engagement items (Collaborative Culture, Personal Growth Opportunities), F1, F2 for Process Efficiency items (Standardized Procedures, Streamlined Operations), HPCM1, HPCM2, HPCM3 for Sustainable Production items (High-Performance Continuous Manufacturing), T1, T2 for Resource Allocation items (Flexible Resource Deployment, Optimized Capacity Utilization)

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	Mean	Standard Deviation	Excess Kurtosis	Skewness	Number of Observations Used
E1	3.185	1.201	-0.681	-0.282	83.000
E2	3.026	1.205	-0.930	-0.051	83.000
F1	3.525	1.253	-0.626	-0.583	83.000
F2	3.442	1.276	-0.843	-0.477	83.000
HPCM1	3.702	1.240	-0.287	-0.779	83.000
HPCM2	3.883	1.228	-0.182	-0.920	83.000
HPCM3	3.762	1.289	-0.356	-0.815	83.000
T1	3.170	1.187	-0.741	-0.332	83.000
T2	3.234	1.105	-0.756	-0.119	83.000

Table 1. Descriptive Analysis and Normality Test

Source: SmartPLS Output, 2025

Table 1 shows the mean and standard deviation values for the variables and indicators utilized in the present investigation, and these were all collected by using the administered questionnaire. The study focused on continuous improvement and sustainable production, assessing multiple key metrics that capture key aspects of these concepts. The stated mean scores, standard deviations, and sample sizes for each indicator provide valuable insights for academics and practitioners. The mean values, all greater than 3, suggest that participants perceived a significant relationship between continuous improvement and sustainable production. Additionally, the comparatively low standard deviations indicate that responses were consistently near the mean, with little variation. These descriptive data demonstrate the complex role of continuous improvement in promoting sustainable manufacturing, underscoring its critical importance.

The sample size exceeded 100; based on the distribution analysis, a skewness absolute value of ±1.0 or less is appropriate for assuming normality. Likewise, kurtosis values between ±3.0 and ±3.0 are suggestive of a normal distribution, whereas values outside this range may indicate excessive peakedness. The findings confirmed that all variables were within the recognized ranges for kurtosis and skewness. This validates the data's eligibility for further analysis and conclusions by confirming that it is regularly distributed.

3.3. Assessment of Measurement Model

With sustainable production (HPCM) as the end variable, this study used employee engagement (EE), process efficiency (PE), and resource allocation (RA) as indicators of continuous improvement to assess the effect of continuous improvement on sustainable production.

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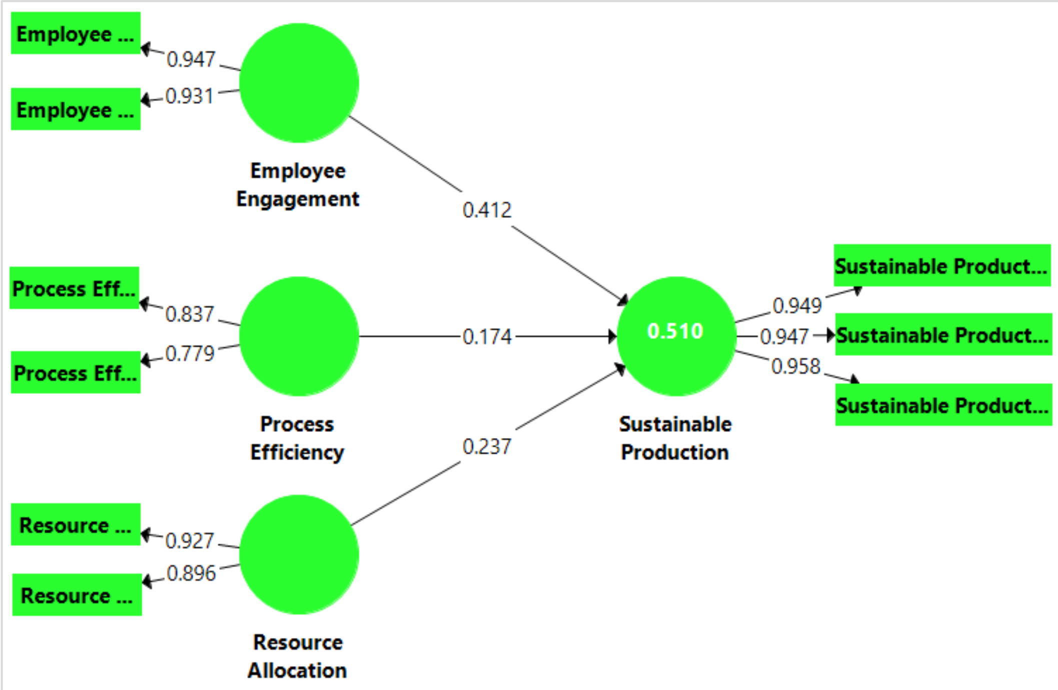

Figure 2: A path model of continuous improvement and sustainable production

Source: SmartPLS Output, 2025

The structural route model examining how continuous improvement affects sustainable production is shown in Figure 2. The model has one dependent variable, sustainable production, and three independent variables: resource allocation, process efficiency, and staff engagement. The results show that all three independent factors have a substantial and favourable impact on sustainable production. This implies that increasing sustainable productivity within organizations requires constant development. The findings also show that every independent variable has a significant impact on sustainable production, emphasizing the necessity for companies to give continuous improvement projects top priority in order to enhance sustainability achievements.

	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Process efficiency	0.773	0.791	0.654
Employee engagement	0.866	0.937	0.882
Sustainable production	0.948	0.966	0.905
Resource allocation	0.797	0.907	0.831

Table 2. Construct Reliability and Validity

Source: Authors Compilation (SmartPLS 3.2.9 Output) 2025

Critical statistical indicators for the validity and reliability of the four latent variables investigated in this study are presented in Table 2. To assess how effectively these variables capture the desired underlying concepts, these indicators are crucial. Cronbach's Alpha and Composite dependability were the two main metrics used to evaluate construct dependability. By analyzing the correlation between its elements, Cronbach's Alpha calculates each latent variable's internal consistency. Internal consistency ratings for all four latent variables were higher than 0.7, which is generally seen as a sign of strong dependability. This implies that the items in each variable above the typical cutoff value of 0.7

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consistently reflect the desired constructions. Another reliability metric, Composite Reliability, which takes into consideration both item correlations and their link to the latent variable, likewise demonstrated values over 0.7 for all variables. This further demonstrates that the constructs in the present research are evaluated with reliability.

Additionally, the Average Variance Extracted (AVE), which assesses each latent variable's convergent validity, is included in the table. The degree to which elements within a construct correspond to one another and convey the same theoretical idea is known as convergent validity. The criteria used in this research successfully overlap in assessing their respective constructs, as evidenced by AVE scores that exceed the recognized minimum of 0.5. In general these results support the good validity and reliability of the latent variables utilized in this study, as shown by their satisfactory convergent validity, high internal consistency, and great composite reliability. This demonstrates their applicability as trustworthy and legitimate constructs in the measuring framework of this research.

	Process efficiency	**Employee engagement**	**Sustainable production**	**Resource allocation**
Process efficiency	0.809			
Employee engagement	0.631	0.939		
Sustainable production	0.583	0.657	0.952	
Resource allocation	0.629	0.574	0.582	0.911

Table 3. Discriminant Validity

Source: Authors Compilation (SmartPLS 3.2.9 Output) 2025

The differentiated nature of the latent variables, resource allocation, employee engagement, sustainable production, and process efficiency, is strongly supported by the discriminant validity results shown in Table 3. Examining if these notions are indeed distinct and not too associated is known as discriminant validity. In the correlation matrix, the off-diagonal values, which indicate correlations between distinct variables, are significantly lower than the diagonal values, which indicate correlations within each variable. This arrangement confirms that each latent variable measures distinct aspects of the broader idea by showing that each latent variable has a stronger link with its individual signals than with other constructs. For instance, resource allocation has a stronger self-correlation than it does with process efficiency, sustainable production, and employee engagement. A similar pattern is seen for all variables in their respective contexts: sustainable production shows a greater connection with itself than with the other factors. These results verify that instead of being overlapping features of a single underlying factor, the latent variables under investigation reflect distinct constructs. Because it clearly distinguishes among the key concepts of resource allocation, employee engagement, sustainable production, and process efficiency, the measurement methodology used in this research is acceptable.

3.4. Multicollinearity

In order to ascertain if either or both of the independent variables are strongly associated and perhaps producing repetitive findings, this assesses the connection between them. To find potential connections involving the independent variables in this research, the Variance Inflation Factor (VIF) is used.

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	Process efficiency	Employee engagement	Sustainable production	Resource allocation
Process efficiency			2.018	
Employee engagement			1.819	
Sustainable production				
Resource allocation			1.810	

Table 4. Inner VIF Values

Source: Authors Compilation (SmartPLS 3.2.9 Output) 2025

The Variance Inflation Factor (VIF) values for the latent variables related to Sustainable Production are shown in Table 4. Process efficiency, employee engagement, and resource allocation all have VIF scores well below the critical threshold of 10. This suggests that these variables do not exhibit significant multicollinearity. Essentially, there are no significant correlations between these variables; therefore, it is safe to include them in the analysis without worrying about multicollinearity.

3.5. Test of Hypothesis

	R Square	R Square Adjusted
Sustainable production	0.510	0.504

Table 5. Coefficient of Determination Score

Source: Authors Compilation (SmartPLS 3.2.9 Output) 2025

The coefficient of determination, or R-squared, which evaluates how well the model matches the data, is shown in Table 5. The model's independent or latent variables account for approximately 51.0% of the variance in sustainable production, as indicated by an R-squared of 0.510. This indicates that the model accurately depicts the variations in the results of sustainable production. A more conservative assessment of the model's fit is provided by the adjusted R-squared value of 0.504. The tight relationship between the adjusted R-squared and the R-squared values indicates that the addition of many independent variables is not responsible for overfitting or needless complexity in the model. All things considered, these figures suggest that the model may adequately explain changes in sustainable output without sacrificing its dependability because of the factors at play.

	Process efficiency	Employee engagement	Sustainable production	Resource allocation
Process efficiency			0.031	
Employee engagement			0.190	
Sustainable production				
Resource allocation			0.063	

Table 6. Assessment of the Effect Size (f2)

Source: Authors Compilation (SmartPLS 3.2.9 Output) 2025

The effect size, sometimes referred to as f-squared, is shown in Table 6 and quantifies the strength of the association between independent variables and the dependent variable in statistical analyses. This study examines the extent to which each latent factor affects "sustainable production." The effect size

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for each independent variable exceeds 0.02, indicating that it is not a significant factor. The results suggest that all variables have moderate effect sizes, indicating that they significantly affect sustainable production. In other words, differences in sustainable output may be moderately explained by changes in one or more of these factors.

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Process efficiency -> Sustainable production	0.174	0.176	0.060	2.877	0.004
Employee engagement -> Sustainable production	0.412	0.409	0.066	6.250	0.000
Resource allocation -> Sustainable production	0.237	0.236	0.066	3.610	0.000

Table 7. Bootstrapping Results Showing Path Coefficient for Structural Model

Source: Authors Compilation (SmartPLS 3.2.9 Output) 2025

The null hypothesis that continuous improvement has no discernible effect on sustainable output was tested using bootstrap path coefficient analysis, as shown in Table 7. The results show that, as elements of continuous improvement, resource allocation, employee engagement, and process efficiency have a major impact on sustainable production. The statistical significance of these linkages is confirmed by looking at the pathways leading from resource allocation, workforce engagement, and process efficiency to sustainable production. Strong grounds to reject the null hypothesis are provided by T-statistics surpassing 1.96 and p-values below the conventional cutoff of 0.05. Thus, sustainable manufacturing is significantly impacted by resource allocation, staff engagement, and process efficiency.

3.6. Discussion of Findings

To test the premise that continuous improvement has no discernible effect on sustainable production, this study assessed its impact. The three main elements of sustainable production, resource allocation, staff involvement, and process efficiency, were found to have statistically significant effects. The null hypothesis was thus rejected, demonstrating that sustainable production is significantly enhanced by continuous improvement. Cunha et al. [40] support this claim, stating that businesses that prioritize continuous improvement programs typically see improvements in sustainability and operational performance. Furthermore, Bai [43] found that employee participation in continuous improvement initiatives enhances manufacturing process efficiency and creativity. As a result, promoting sustainable production requires constant development. This underscores the importance of a culture of continuous improvement within organizations, as it can lead to significant advances in sustainable operations. Encouraging staff members to actively engage in such projects fosters creativity and improves sustainability performance.

4. Conclusion

The research discovered that sustainable production efforts in the five sugar manufacturing firms studied (Dangote Sugar Refinery, Golden Sugar Company, Flour Mills Sugar Company, Sunti Golden Sugar Estate, and Savannah Sugar Company) are positively impacted by continuous improvement

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factors, particularly employee engagement, resource allocation, and process efficiency. These firms demonstrate that appropriate resource allocation ensures critical operations receive adequate support for continuous operations. Encouraging active employee participation contributes to the development of a sustainability-focused organizational culture. Furthermore, increasing process efficiency reduces energy consumption and waste generation, promoting environmentally responsible production methods within these specific organizational contexts.

4.1. Recommendation

Based on findings from the five sugar manufacturing firms studied, management should prioritize developing context-specific resource allocation strategies, enhancing employee engagement initiatives, and streamlining operational processes to support sustainable production goals. For these specific organizations, implementing systematic resource allocation methodologies can ensure sustainability initiatives receive the necessary financial and technical support. Additionally, establishing regular employee feedback mechanisms and training programs can foster ownership and commitment to sustainable production objectives. While these recommendations are derived from sugar manufacturing contexts, managers should adapt these strategies to their specific operational realities and resource constraints.

4.2. Limitations

This study has several limitations that should be acknowledged. First, the sample was limited to five sugar manufacturing companies in Nigeria, which may limit the generalizability of findings to other sectors or geographical contexts within Nigeria's manufacturing industry. Second, the cross-sectional design of the study provides a snapshot at a single point in time, limiting the ability to make strong causal inferences about the relationships between continuous improvement practices and sustainable production outcomes. Third, the study relied on self-reported measures, which may be subject to social desirability bias and common method variance. Fourth, the geographic concentration of the sampled firms may not capture regional variation in the implementation of continuous improvement across Nigeria. Future research should employ longitudinal designs, include multiple manufacturing sectors, and incorporate objective performance measures alongside survey data to address these limitations.

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Conflicts of Interest

The author declares no conflict of interest. The author has read and agreed to the published version of the manuscript.

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Appendix A

Measurement Items: All items measured on 5-point Likert scale

Employee Engagement (EE)

1. CC: Our organization encourages teamwork in implementing sustainable practices
2. PGO: The organization provides training on sustainable production methods

Process Efficiency (PE)

1. StdP: Our production processes follow standardized protocols
2. **SO: Production workflows minimize waste and redundancy**

Resource Allocation (RA)

1. FRD: Resources are allocated flexibly based on sustainability priorities
2. **OCU: Production capacity is used efficiently to minimize environmental impact**

Sustainable Production (SP)

High-Performance Continuous Manufacturing (HPCM)

1. HPCM1: Our production processes minimize environmental footprint
2. HPCM2: Sustainability is integrated into daily production activities
3. HPCM3: The organization balances economic and environmental performance