GAS Journal of Economics and Business Management (GASJEBM)

Volume 2 | Issue 12, 2025 Homepage: https://gaspublishers.com/gasjebm-home/ ISSN: 3048-782X

Impact of Facility Layout and Workflow Optimization on Production Efficiency

Habib Abdulrahman Yusuf[1], Usama Ibrahim Achida[2] & Aliyu Mohammed[3]

[1]Student, Department of Business administration, School of Science and Information Technology, Skyline University, Nigeria, Kano.
[2]Student, Department of Business administration, School of School of Science and Information Technology, Skyline University, Nigeria, Kano.
[3]Faculty, Department of Management, School of Arts, Management and Social Sciences, Skyline University Nigeria, Kano.

Received: *25.10.2025* | ***Accepted:*** *22.11.2025* | ***Published:*** *02.12.2025*

***Corresponding Author:** Aliyu Mohammed

DOI: *10.5281/zenodo.17786939*

Abstract **Original Research Article**

In today's manufacturing settings, inefficiencies relating to the layout of manufacturing facilities and inefficient work processes are significant factors in rising operational costs, longer production lead times and less efficiency. This research examines the effect of layout planning of facilities and flow optimization on production efficiency by focusing on three manufacturing settings, which include global, African, West African and Nigerian manufacturing. The main goal is to investigate the aspects of systematic layout designs or optimized workflows that optimize material handling, labor productivity, throughput, and resource utilization that can resolve bottlenecks and inefficiencies in the operation. Guided by conceptual research approach, the research uses a systematic examination of secondary sources of data (i.e., peer-reviewed journal articles, books, industry reports, historical information) to synthesize understanding of facility layout and workflow management. The analysis shows that by integrating the application of layout optimization approaches (e.g. SLP, ALDEP) and workflow optimization (lean tools, simulation, AI and AR/VR) offers measurable improvement of efficiency in production, cost reduction and sustainable operating performance. Key challenges identified include low adoption of technology in use, resource challenges and implementation barriers in developing economies. The study suggests that manufacturing managers and policymakers adopt digital tools, simulation software, and best practices in facility and workflow design to achieve facility operational excellence. Ultimately, the paper underscores the importance of the strategic layout and the management of workflow in driving manufacturing systems productivity, competitiveness and sustainability.

Keywords: Facility Layout, Workflow Optimization, Production Efficiency, Simulation, Lean Manufacturing.

1.0 Introduction to the Study

1.1 Background of the Study

Efficient production systems are one of the keys to competitive manufacturing in today's global economy. Facility layout and workflow design are important factors in determining production efficiency, such as material handling costs, production speed, labor productivity, and operational sustainability (Xu, Xu, & Su, 2024; Zuniga et al., 2020). Globally, organizations have long been considering ways to use simulation, digital instruments, and optimization algorithms to optimize facility configurations and optimize workflow

processes, but notable classifications can be found in manufacturing industries such as the automobile assembly industry, electronics manufacturing, and warehousing (Hau, 2020; Tulli, 2023; Susse, Ahrens, Richter-Trummer, & Ihlenfeldt, 2023). It is especially noteworthy in environments that experience high recommendation demand, where inefficiencies in material flow, spatial utilization and process sequencing can result in sizeable within productivity and revenue losses (Malega, Daneshjo, & Stofkova, 2025; Laomongkholchaisri et al., 2024). In Africa, manufacturing sectors are frequently hampered by an issue of having to manage legacy facilities, ineffective layouts, and poor uptake of modern workflow management technologies - leading to higher operational costs and low competition (Mohammed, 2023; Sundararajan & Mohammed, 2022). West African countries including Nigeria are faced with further challenges such as infrastructural inadequacies, skills gaps and poor level of technology adoption, which add to inefficiencies in production facilities (Aliyu, 2024; Mohammed & Sundararajan, 2023). Despite these challenges, there is increasing interest in using systematic layout planning, workflow optimization methods and digital solutions to improve production efficiency in small and medium-scale enterprises (Setyaningrum, Erthamevia, Febriana, & Setyanti, 2025; Mohammed, Shanmugam, Subramani, & Pal, 2024).

In the Nigerian context, manufacturing firms are starting to appreciate the need to integrate improvements in facility layout with the redesign of workflow to achieve sustainable operational performance. Evidence suggests that optimized facility layouts when coupled with various work flow interventions such as lean principles, automation and scheduling through simulation can significantly reduce material handling times, labor idle periods and operational bottlenecks (Karaman et al., 2025; Sundararajan & Terkar, 2022; Mohammed, Jakada, & Lawal, 2023). Furthermore, these improvements are not only economically focused but also help to make a contribution to environmental and social sustainability through reduced energy consumption, lowered waste, and enhanced worker ergonomics (Haddou Amar, Abouabdellah, & El Ouazzani, 2018; Xu, Xu, & Su, 2024). Globally and locally the nexus of facility layout, a work-flow optimization, and production efficiency is becoming more crucial for enterprises to gain competitive advantage. While various attempts have been made at addressing issues of facility layout planning and improving the workflow across developed economies (Kanbur, Suping, & Duan, 2020; Zuniga et al., 2020), there still exists an apparent research deficit in developing integrated and context-specific strategies for the manufacturing industries in and especially Nigeria. Breeding and/or focus on this gap represents a major step toward establishing sustainable production systems that integrate the goals of operational efficiency with economic, social, and environmental objectives (Mohammed, 2023; Setyaningrum et al., 2025).

1.2 Problem Statement

Despite the recognition of facility layout and optimizing material flow processes as factors in boosting production efficiency, most manufacturing enterprises in different parts of the world still suffer from inefficient facility layout, inefficient material flow, and work process bottlenecks (Xu, Xu, & Su, 2024; Zuniga et al., 2020). Inefficientities in production facilities produce higher operational expenditures, longer production lead times, higher levels of labour use, and lower overall productivity. Even for technologically advanced economies, integrating layout optimization with workflow management challenges companies because of intricate production processes and dynamic market needs (Malega, Daneshjo, & Stofkova, 2025; Susse, Ahrens, Richter-Trummer, & Ihlenfeldt, 2023). In Africa manufacturing operations have to deal with obsolete facilities, as well as low uptake of digital tools and low availability for sophisticated optimization methods (Mohammed, 2023; Sundararajan & Mohammed, 2022). These factors lead to further inefficiencies and lack of competitiveness of African manufacturing firms against the world market. Specifically, in West Africa and Nigeria, the manufacturing enterprise is facing additional problems such as poor infrastructural support, low and inconsistent energy supply, low workforce productivity and lack of

knowledge on modern facility planning methodologies (Aliyu, 2024; Mohammed & Sundararajan, 2023). These constraints add extra to the extended material handling times, increased costs of manufacturing and the delivery time of the goods finally impact the profitability of the firm and its market performance [Setyaningrum, Erthamevia, Febriana, Setyanti, 2025; Mohammed, Shanmugam, Subramani, Pal, 2024].

Moreover, there is scarcity of empirical studies for integrated solutions of facility layout and optimizing workflow on the Nigerian manufacturing scenario. Most existing studies are either limited to layout planning or improvements in the workflow that do not consider the synergy between them in terms of production efficiency and resource utilization, and their impact on sustainability results (Karaman et al., 2025; Sundararajan & Terkar, 2022). This gap is a crucial challenge to managers and policymakers, seeking evidence-based strategies to better operational performance, production capacity and sustainable growth in manufacturing firms. Consequently there is an urgent need to research into ways or possibilities of how optimized facility layout and the workflow process can be mutually used to reduce the material handling costs, minimize the bottleneck in the production process and improve the overall production efficiency especially in the context of manufacturing industries in Nigeria (Mohammed, Jakada, & Lawal, 2023; Haddou Amar, Abouabdellah, & El Ouazzani, 2018).

1.3 Significance of the Study

The study on the impact of facility layout and optimized flow of work in production efficiency has enormous implications in manufacturing operation at global, regional, and national levels. Globally, efficient facility layouts and optimized working processes are of utmost importance to facilitate better productivity, lower operation costs, and increase average competitiveness in the age of Industry 4.0 and mass customization (Zuniga et al., 2020; Susse, Ahrens, Richter-Trummer, & Ihlenfeldt, 2023). Organizations which implement systematic solutions of layout and workflow optimization, which can be deemed to be experiencing smoother material flows, which can be said to reduce production lead times and resource utilization which is a very important criterion for dealing with ever-growing customer requests, and ensuring adequate quality.Malega, Daneshjo, & Stofkova (2025) ORG 10.2337/CEE.2025.02501 Material flow optimization in the food industry for better productivity for clients: Application of production efficiency principles to manufacturing case studies Organizations that adopt systematic layout and workflow optimization practices In the African context where many manufacturing companies are operating in infrastructural and resource-constrained environments, optimizing a facility's layout and workflow can make a significant difference in optimizing operational efficiency and competitiveness. By minimizing unnecessary material handling, workflow bottleneck and enhancing labour productivity, manufactured goods can enjoy better throughput, lower production costs and sustainability outcomes (Mohammed, 2023; Sundararajan & Mohammed, 2022).

Within West Africa, and especially Nigeria, the research takes on even greater significance because of the issues associated with outdated facilities, unstable power supply, and low adoption of modern aspects of manufacturing (Aliyu, 2024; Mohammed & Sundararajan, 2023). By offering empirical evidence and practical recommendations for optimized facility layout and process workflow design, the study can raise the unconscious nature of managers in Nigerian manufacturing enterprises to make acceptable decisions to enhance the efficiency of operations, maximize the utilization of resources as well as to enhance competitiveness in the local and international market. From an academic point of view, the research adds to the emerging practices known about integrated facility layout and optimisation of flow in developing economies. It addresses a gap in the literature where most studies investigate these individual elements, in a more holistic way and interlinking between the layout design and the efficiency in the workflow for sustainable production performance (Haddou Amar, Abouabdellah, & El Ouazzani, 2018; Mohammed, Jakada, & Lawal, 2023).

Furthermore, the results of this research can inform the policy-making process and help guide the creation of targeted interventions, such as incentives for adoption of technology, workforce training programmes, and infrastructural facilities, so as to create an enabling environment for industrial growth and economic growth. At the end of the day, causal importance of operational design to organisational goals workforce capabilities of the workforce and sustainability objectives is crucial for functionality granting long-term resilience and competitiveness to manufacturing enterprises. (Mohammed, Shanmugam, Subramani, & Pal, 2024; Sundararajan, and Terkar, 2022).

1.4 Research Objectives

The main aim of this study is to investigate the impact of facility layout and workflow optimization on production efficiency in manufacturing enterprises, with particular reference to global, African, West African, and Nigerian contexts. The study is guided by the following specific objectives:

1. To examine the influence of systematic facility layout design on material handling, production lead time, and overall operational efficiency.
2. To assess the effect of workflow optimization on labor productivity, resource utilization, and reduction of bottlenecks in manufacturing processes.
3. To identify key factors, challenges, and best practices in implementing optimized facility layouts and workflows in developing economies, particularly Nigeria.
4. To evaluate the role of technology adoption, digital tools, and simulation-based optimization methods in enhancing facility layout and workflow design for sustainable production performance.
5. To provide actionable recommendations for manufacturing managers, policymakers, and stakeholders on achieving operational efficiency through integrated layout and workflow optimization.

1.5 Research Questions

To achieve the stated objectives, the study seeks to answer the following research questions:

1. How does facility layout design impact material handling efficiency, production lead time, and operational costs in manufacturing enterprises?
2. What is the relationship between workflow optimization and labor productivity, resource utilization, and reduction of process bottlenecks?
3. What are the main challenges and factors influencing the implementation of optimized facility layouts and workflows in Nigerian manufacturing firms?
4. How can technology adoption, including simulation software and digital tools, enhance the design and optimization of facility layout and workflow for sustainable production?
5. What practical recommendations can be proposed to manufacturing managers and policymakers to improve production efficiency through integrated facility layout and workflow optimization?

2.0 Literature Review

The literature review offers a thorough insight into the theoretical and empirical basis of facility layout planning and workflow optimization and how it affects production efficiency. It explores the concepts, methodologies, tools and practical application worldwide, in Africa, West Africa and Nigeria and gaps and possibilities for further research.

2.1 Conceptual Review

This section examines some of the concepts that will be relevant to the study: facility layout planning, optimizing workflow, integrating with technology and digital tools.

2.1.1 Facility Layout Planning

Definition and Types of Facility Layouts

Facility layout planning (FLP) can be

described as the strategic locations of physical resources such as machinery, equipment, storage areas, and workstations in a production facility in order to provide for smooth flow of production, materials, etc., and reduces material handling costs and improves overall operational efficiency (Xu, Xu, & Su, 2024). A right-handed well-spinner a kontset's work bottlenecks, optimiz labor utelization and to support move materials and productt efficiently.

Facility layouts are commonly categorized into four main types:

1. **Process Layout:** Orient or position the equipment and workstations according to similar processes or functions. Ideal for job-shop operations in which production is in varied products and in low volume is involved. This layout focuses on flexibility and can lead to more material handling costs (Zuniga et al., 2020).
2. **Product Layout:** Lays out workstations in a sequence of the production process. Suited for mass production and reducing the number of handling operations and thus shortening the cycle time, unfortunately this layout lacks flexibility for changing the product (Tulli, 2023).
3. **Cellular Layout:** Form groups of machines and processes into cells according to similar product families /operations. This hybrid approach involves both efficiency and flexibility that supports the concept of lean production and shorter transit distances (Shafira et al., 2025).
4. **Fixed-Position Layout:** Stations the product and moves resources, tools and labor to the production site. Common in large scale and complex products such as shipyards or assembling aircrafts (Junior et al., 2023).

Systematic Layout Planning (SLP) and ALDEP Methods

Systematic Layout Planning (SLP) is a methodical approach to analyzing the relationship of flow between processes of a workflow and the flow of materials and the space required for the design of efficient layouts (Laomongkholchaisri et al., 2024). SLP focuses on qualitative and quantitative assessment describing the work through use of relationship charts, activity diagrams, and dimensionless layouts to optimise production efficiency. For example, in a cake production factory, SLP helped reduce travel distances by 37.69%, as well as improved the operational efficiency by reducing unnecessary movement (Shafira et al., 2025). The ALDEP (Automated Layout Design Program) method is a complement to SLP that is used for algorithmic optimization for department-level layouts. ALDEP assesses spatial needs, inter-departmental interactions, and inter-department preferences to produce best layouts, which is frequently represented in 2D and 3D models. This approach has been successfully applied in industries like wooden cable reels production and printing facilities where manufacturers can strategically locate their production and office departments for higher efficiency (İnce & Taşdemir, 2024; Karaman et al., 2025).

Role of Digital Tools, Simulation, and AR/VR in Layout Design

The combination of digital tools, simulation software, and augmented/virtual reality (AR/VR) technologies has helped to disrupt facility layout planning. Digital simulations show the possibility for practitioners to model scenarios of workflows, material handling and spatial arrangements in order to test them before physical implementation. Tools such as Plant Simulation and Witness software have been used to help ensure better layout efficiency, fewer bottlenecks, optimize manpower utilization and show measurable improvements in production output (Gore, 2018; Malega, Daneshjo, & SStofKOVA, 2025). AR and VR technologies enhance the planning of layouts further by giving you immersive visualization of layouts. In a next phase, 3D models enable designers to interact with their model, be able to reconfigure machine positions, to simulate production sequence in real-time, and to promote a more rapid decision-making process and spatial planning (Hau, 2020). This ease-usage is of great use to industries that need flexibilities, manufacturing of SMEs, warehouses and assembly lines etc where physical errors and testing is costly

and time consuming (Mojumder & Nuruzzaman, 2025; Laomongkholchaisri et al., 2024). The use of these digital tools is part of Industry 4.0 principles, allowing data-driven decisions to be taken, predictions to be made, and production layouts to be optimized in a sustainable manner. Studies suggest that in facilities that use simulation-based or augmented reality-aided layout designing and plan a facility, they have found huge enhancements in material flow efficiency, various conditions that station and transport as far as handling and productive labor (Setyaningrum et al., 2025, 2022; Xu, Xu, & Su, 2024).

Layout Optimization Metrics

Optimizing a facility layout involves a significant amount of consideration of multiple quantitative and qualitative metrics intended to make production as efficient and cost-effective as possible. Key metrics include:

1. **Material Flow:** Efficient flow of raw materials and work-in-progress and finished goods decreases handling time and minimizes delivery of production time. Studies have shown the optimization of material flow is able to indirectly reduce the total travel distance by more than 30%, affecting the cycle time and throughput directly (Laomongkholchaisri et al., 2024, Setyaningrum et al., 2025).
2. **Space Utilization:** Effective use of space without compromising flexibility since the necessary space is allocated that allows for future expansion or process change. Digital simulations and layout optimization algorithms, e.g. ALDEP and Plant Simulation, allow designers to model various spatial organization in a way to ensure the best utilization (Ince & Taşdemir, 2024; Malega, Daneshjo, & stoflova, 2025).
3. **Handling Costs:** Reducing unnecessary handling of materials reduces handling costs. Layout strategies, when used in conjunction with planning through simulation, have been shown to decrease the cost of handling (Xu, Xu, & Su, 2024) by simplifying the production sequence and the placement of equipment.
4. **Workflow Efficiency:** Optimized layouts improve the flow of the process by optimizing bottlenecks and idle time to get better production rates and responses. Real-time evaluation of the changes in the workflow is possible through AR-assisted layout planning, which can be used for ongoing improvement efforts (Hau, 2020; Mojumder & Nuruzzaman, 2025).

Human Factors, Safety, and Ergonomics in Layout Planning

Human-centered considerations are important when designing a facility layout. Poorly laid out plans can cause fatigue, accidents, and lower productivity. Ergonomic design is about having a workstation or equipment, and pathways that humans can work in and do the work more comfortably thus reducing musculoskeletal strain and improving the overall safety aspect.

1. **Ergonomics:** Using ergonomics in the design of workstations and workflows can help to improve worker comfort, reduce injury risks, and improve productivity. For instance, an implementation of ergonomic working desk and optimized task sequences has been shown to significantly reduce movement times as well as increase operator satisfaction (Setyaningrum et al., 2025).
2. **Safety:** Safety zones, emergency exits, and risk reduction for equipment operation and material handling are all factors that must be taken into account when laying out a facility. Digital simulations can be used to model human movement and predict safety hazards before the layout is implemented (Laomongkholchaisri et al., 2024).
3. **Human-Machine Interaction:** Efficient layouts help in reducing unnecessary worker-machine interactions as well as simplify manual handling and aid in automating such processes, thereby optimizing the workflow and reducing the potential for errors (Tulli, 2023).

Incorporating these human factors together with purely optimization metrics ensures that layouts are not only efficient regarding material flow and expenses, but sustainable, safe and conducive to long-term workforce performance (Aliyu, 2024; Sundararajan & Mohammed, 2022).

2.1.2 Workflow Optimization (IV2)

Concept of Workflow Analysis and Process Mapping

Workflow optimization aims at considering and implementing an optimized sequence of tasks and interactions within a production system so that the process becomes as efficient as possible and bottlenecks in operations can be reduced. Workflow analysis is the professional examination of task sequences and material flow and the interdependent work in between departments to determine inefficiencies and redundancies (Xu, Xu, & Su, 2024; Zuniga et al., 2020). Process mapping tools (flowcharts, value stream maps - VSM etc.) visually depict the flow of materials and information and enable managers to identify important bottlenecks, waiting time and unnecessary operations (Sundararajan & Terkar, 2022). Effective workflow analysis helps decision-making about the reconfiguration of processes to better throughput, lead times, resource allocation while also keeping quality standards intact. For instance, VSM can be used to measure cycle times and non-value-added activities, which can then be used to gain actionable knowledge on how to streamline operations (Sundararajan, N., & Terkar, R., 2022).

Lean Manufacturing Tools: 5S, VSM, Work Standardization

Lean manufacturing principles are an intrinsic part of workflow optimization and provide structured ways of optimizing operations:

1. **5S Methodology:** This method (Sort, Set in order, Shine, Standardize, Sustain) of workplace organization reduces wastage, and creates a better spatial organization, which in turn, maximizes productivity of workers by creating a clean, and well organized environment (Roca-Limache, Quispe-Leon, & Tupia-De-La-Cruz, 2025).
2. **Value Stream Mapping (VSM):** VSM identifies and removes non-value added activities and optimizes the process flow and the overall production cycle. Studies show that VSM implementation may save more than 35% reduction on materials handling and movement, which will improve the efficiency and lower the cost of operation (Laomongkholchaisri et al., 2024; Setyaningrum et al., 2025).
3. **Standardization of Work:** Standardization of work procedures helps in achieving consistency of performance, avoid varying degrees and assist in training and also in quality control. Standardization also promotes ergonomic optimization, managing the tasks to be done with respect to human capabilities and safety aspects (Setyaningrum et al., 2025; Cabusas et al., 2023).

Simulation-Based Optimization (Plant Simulation, Witness, Arena)

Simulation tools are widely used to evaluate and optimize the workflow before an actual physical implementation minimizing trial and errors and cutting costs:

1. **Plant Simulation:** Offers you digital modeling of manufacturing layouts that allow managers to experiment with various production orders, fabric circulating and allotting choices. Plant Simulation enables correct estimation of throughput, bottlenecks, and space utilization, which guarantees data-driven layout decisions (Malega, Daneshjo, & Štofková, 2025).
2. **Witness Simulation:** Helps to model complex assembly line operation, analyse manpower utilisation, identify bottleneck operations and forecast production output under different scenarios. Simulation results have shown production rate improvements of up to 12% as well as huge reductions in manpower requirements (Gore, 2018).
3. **Arena Simulation:** Offers a flexible workflow modeling capability in discrete event simulation

that is useful for optimizing resource allocation, task sequencing and process integration. Arena has been successfully applied in manufacturing studies to redesign layouts as well as optimize overall operational efficiency (Sundararajan & Terkar, 2022).

Integrating lean tools with optimization based on simulations enables organizations to attain better efficiency, less waste, and guarantee adaptive design processes of the workflow around evolving needs for constraints of demand, technology, or production capability.Tulli, M. (2023), Hau, T. (2020), Roca-Limache, L., De Pourtales, N., Kuenz, D. (2025) Integration of lean and simulation-based optimization methods: Organizations can achieve improved efficiency, lower waste, and ensure adaptive design processes of their workflow can adapt to future capacity changes in demand, technology, or production.

AI-Driven Workflow Management and Automation

Artificial intelligence (AI) has been a rising trend in the optimization of workflows. AI-driven systems allow for real-time monitoring, predictive analysis, and automated decision-making in driving greater efficiency in the production process and limiting human error. Techniques like machine learning, reinforcement learning and hybrid architectures of artificial intelligence have been employed for optimizing task allocation, inventory management and routing of materials within complex production and warehouse settings (Mojumder & Nuruzzaman, 2025; Xu, Xu, & Su, 2024). Studies show that AI-driven workflow systems can help achieve reductions in cycle times of 15-45%, increase space utilization of 20-35% and contribute to increased precision of operation to above 98% (Mojumder & Nuruzzaman, 2025). AI can also be used in combination with production scheduling algorithms, such as shortest processing time (SPT), longest processing time (LPT) and center of gravity (CoG) to dynamically optimise workflows based on changing demand, machine availability or labor constraints (Hau, 2020; Tulli, 2023).

Integration of Facility Layout with Workflow Optimization for Operational Efficiency

Facility layout and optimization of workflow are related factors that affect the overall production efficiency, reduction of costs, and utilization of resources. A well-designed facility layout reduces material handling distances, decreases congestion of the facility, facilitates efficient task sequence and the workflow optimization ensures tasks are executed in the most efficient way (İnce & Taşdemir, 2024; Karaman et al., 2025). Digital tools, simulation models, and augmented reality (AR) platforms allow planners to test various configuration options of a plant layout with scenarios of the production workflow to find the one that will optimize throughput and lowest operational costs (Hau, 2020; Laomongkholchaisri et al., 2024). For instance, the combination of systematic layout planning (SLP) or automatic layout designing elements (ALDEP) together with simulation-based workflow analysis enables an analysis of space usage, human ergonomics, safety and task sequencing simultaneously (Setyaningrum et al., 2025; Malega, Daneshjo, & Štofková, 2025). By integrating facility layout design, artificial intelligence-driven optimization of workflow, organizations can build agile, flexible and sustainable production systems that can adapt to the global competitive forces and local production challenges, especially in developing economies such as West Africa and Nigeria (Xu, Xu, & Su, 2024; Tulli, 2023).

2.1.3 Production Efficiency (DV)

Definition and Measurement of Production Efficiency

Production efficiency means the ability of a manufacturing system or service system to produce outputs in a way that accomplishes the intended goal and reduces the amount of waste with the greatest added value (Kovács 2017; Cabusas et al 2023). As it is the critical metric for operational performance and competitiveness, it is especially important in sectors with high customer demand and fast-changing technologies. Efficiency is usually measured using the efficiency of a system that reflects the effectiveness with which targeted output

is achieved with the least reproduction of resources.

Key Indicators of Production Efficiency

There are a number of indicators you can use to assess production efficiency:

1. Throughput: The speed by which the products are produced in a given period. Optimized layouts and streamlined work-flows bring the throughput up with the involvement of minimizing bottlenecks and delays (Shafira et al., 2023; Sundararajan & Terkar, 2022).

2. Cycle Time: Complete time that is necessary to perform a production process from beginning to end. A decrease in cycle time is realized by such effective task sequencing, material handling and machine placement (for example Zhou et al., 2014; Liao et al., 2014; Dong et al., 2015; Zhang et al., 2015; Zhang et al., 2015; Zhong et al., 2015; Tu et al., 2016; Wu et al., 2016; Lo & Le, 2016; Dong et al., 2016; Lo et al.,

3. Labor Productivity: Quantity of output divided by the amount of time to produce that output. Layouts that characterize activities with less useless motion and labor flows that standardize activities contribute to increased labor efficiency (Roca-Limache et al., 2025; Setyaningrum et al., 2025).

4. Waste Reduction: Eliminating wasteful motives, unnecessary movements and faultless outputs. Lean tools such as 5S, Value stream mapping (VSM) and work standardization play a central role in reduction of waste (Setyaningrum et al., 2025; Sundararajan & Terkar, 2022).

5. Resource Utilization: Resource utilization is the effective use of machinery, materials, and space. Optimized layouts ensure that equipment and workstations are located in a way that allows maximum accessibility with minimum idle time (Masoud et al., 2019; Malega, Daneshjo, & Hofekova, 2025).

Economic, Environmental, and Operational Aspects of Efficiency

Production efficiency contains economic, environmental, and operational aspects which work together to determine the overall performance and sustainability of production systems. Economically, efficiency plays a direct role in cost reduction during operations, production time, and profitability by optimum resource uses and simplified production processes (Kovacs, 2017; Cabusas et al., 2023). Environmentally, efficient production practices are favorable to sustainability from a conservation standpoint through reduction of energy consumption, material waste, carbon emission and through optimized workflows and facility layouts (Xu, Xu, & Su, 2024; Haddou Amar, Abouabdellah, & El Ouazzani, 2018). In an operational sense, increased efficiency will make the system more robust to system reliability, enhance workplace safety and ergonomics, while allowing an organization to be more agile in responding to the changes in demand or production constraints (Lin & Wang, 2019; Laomongkholchaisri et al., 2024). Collectively, these dimensions explain how production efficiency is a cornerstone for winning the battle for sustainable competitiveness, when it comes to manufacturing and service operations in the modern era.

Impacts of Workflow and Layout Optimization on Performance and Sustainability

Facility layout and workflow optimization is tightly related to the production efficiency and sustainability results. Studies show that a systematic planning, analysis using simulations and AI-assisted workflow management may be able to improve significantly the operational metrics (Hau, 2020; Mojumder & Nuruzzaman, 2025). For example, minimizing the distance of material movements in built layouts lowers the cycle times and energy consumption (Laomongkholchaisri et al., 2024). Similarly, lean workflows practices and digital simulations are optimization of labor productive and throughput while maintaining safety and ergonomic standards (Setyaningrum et al., 2025; Roca-Limache et al., 2025). Integrating facility layout and workflow optimization therefore not only promotes short-term operational performance but also helps address the long-term sustainability of economic, environmental, and social development which is becoming increasingly important for manufacturing organizations in Nigeria, the West Africa, and globally (Xu, Xu, & Su, 2024; Tulli, 2023).

2.2 Theoretical Framework

Lean Manufacturing and Theory of Constraints (TOC) for Process Efficiency

Lean manufacturing principles include eliminating waste, constant process enhancement, and value creation maximization in production systems (Setyaningrum et al., 2025; Sundararajan & Terkar, 2022). Facility layout and workflow optimization are key aspects of lean manufacturing because they directly affect the flow of materials, cycle time, and areas where the facility is blocked. The Theory of Constraints (TOC) supports lean principles in recognizing the most important limiting factors (constraints) in the production process and putting most improvements around bottlenecks (Zubniga et al. 2020; Malega, Daneshjo, & Stfoufka, 2025). Combining TOC with optimized facility layouts and simplified work flows ensures that throughput is maximized, idle time is at a minimum and resources are deployed effectively. For example, simulation-based applications such as Plant Simulation and Arena can be used to model the bottlenecks in the workflow process and suggest layout changes to boost the overall system's efficiency (Hau, 2020; Laomongkholchaisri et al., 2024).

Resource-Based View (RBV) for Competitive Advantage

The Resource-Based View (RBV) assumes that sustainable competitive advantage is attained by exploiting valuable, rare, inimitable, and non-substitutable (VRIN) resources (Wernerfelt, 1984; Barney 1991). In the context of manufacturing, operational assets, including well-designed two facility arrangements, optimized flow of the production levels, trained human resources are a case in point to be strategic resources that antecedent precise production efficiency (Karaman et al., 2025; Xu, Xu, & Su, 2024). By aligning facility layout and optimising workflow based on RBV, organisations can create not only positive short-term performance measures such as throughput and cycle time but also long-term strategic capabilities that will help them gain more flexible operations, lower costs, and enable sustainable growth (Mohammed, 2023; Mojumder & Nuruzzaman, 2025).

Rationale for Using These Frameworks

The combination of Lean Manufacturing/TOC and RBV offers a two-sided look:

1. Operational Perspective (Lean/TOC): Emphasizes on the efficiency of process and the elimination of bottlenecks, reducing waste, and real-time decision making for improving production efficiency on the spot (Setyaningrum et al., 2025; Laomongkholchaisri et al., 2024).

2. Strategic Perspective (RBV): Focuses on highlighting the long-term competitive advantages came from the effective utilization of physical or human and technological resources through optimized layouts and work flows (Karaman et al., 2025; Xu, Xu, & Su, 2024).

Together, these frameworks provide the rationale for this study to focus on facility layout as well as optimizing workflow as a roadmap to operational tactic and strategic asset to achieving sustained production efficiency in the context of global, African, West African, and Nigerian manufacturing.

2.3 Linkages between Theories, IV, and DV

Optimized Facility Layouts and Resource Utilization (RBV)

According to the Resource-Based View (RBV), the operational resources including the well-structured facility layouts can be used to yield the sustainable competitive advantages (Karaman et al., 2025; Xu, Xu, & Su, 2024). Optimized facility layout helps in reducing the unnecessary material handling and minimises the travel distances as well as maximize the utilisation of the space that directly increments into improved productivity and reduced operational cost (Ince and Taşdemir, 2024, Malega, Daneshjo, and Shtofková, 2025). By ensuring layout design as a strategic resource towards the enterprise this can give the efficiency in the long run, and aid production systems to scalability and adaptability (Mohammed, 2023; Mojumder & Nuruzzaman, 2025).

Workflow Optimization and Production Throughput (Lean/TOC)

Workflow optimization based on Lean Manufacturing principles and the Theory of Constraints (TOC), which means optimizing and removing bottlenecks, task standardization, and streamline process flows (Setyaningrum et al., 2025; Sundararajan & Terkar, 2022). Efficient workflows improve throughput, cycle times, and wastage, thereby improving the operational performance. Techniques such as value stream mapping (VSM), 5S, and optimization using simulation (Plant Simulation, Arena, Witness) make it possible to continuously assess and optimize flow processes to production objectives (Hau, 2020; Laomongkholchaisri et al., 2024). AI-powered workflow management further makes it effortless to achieve real-time process adjustment and predictive maintenance and assign the automation tasks to maintain high efficiency levels (Mojumder & Nuruzzaman, 2025; Tulli, 2023).

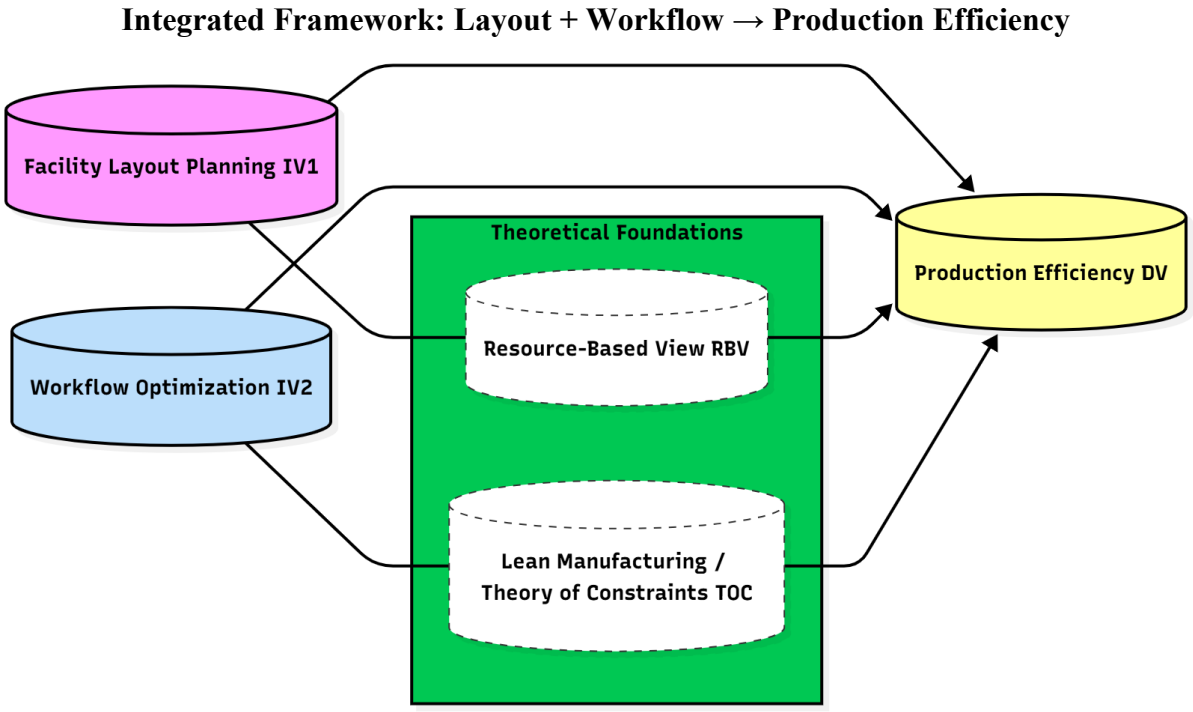

Figure 2.1: Integrated Conceptual Framework of Facility Layout and Workflow Optimization on Production Efficiency

Source: Developed by the authors based on literature review (Tulli, 2023; Mojumder & Nuruzzaman, 2025; Xu, Xu, & Su, 2024; Karaman et al., 2025; Setyaningrum et al., 2025).

The diagram shows the integrated conceptual framework for analyzing the effects of facility layout planning IV1 and optimization of workflow (IV2) on production efficiency (DV). Facility layout planning directly affects the production efficiency because it can optimize the production space layout, optimize the material flow and handling cost design, and workflow optimization improves production efficiency through streamlined production processes, reduction of bottlenecks, and standardization of tasks (Xu, Xu, & Su, 2024; Tulli, 2023). The theoretical base is the foundation of our study consisting of Resource-Based View (RBV) and Lean Manufacturing/TOC. The following elements provide the theoretical foundation of the developed model: RBV focuses on strategic use of harnessing

physical and operational assets to create sustainable competitive advantage, while Lean/TOC focuses on eliminating waste and enhancing the process throughput (Mojumder & Nuruzzaman, 2025; Malega, Daneshjo, & Štofková, 2025). The framework illustrates the both direct impacts of the independent variables on productivity of production efficiency and indirect impacts through the theoretical principles to show the enhancements that integrated approach can bring to the operational performance and labours productivity and utilization of the resources to the manufacturing sadness activities in global, African, West Africa and Nigeria (Karaman et al., 2025; Setyaningrum et al., 2025.

2.4 Empirical Review

Empirical studies have repeatedly shown just how important facility layout and optimizing job flow are as they help drive efficiency in production in a variety of manufacturing industries. For example, a study on cable drum manufacturing and printing companies in the Chief planning job areas with algorithms such as ALDEP and digital modelling tools made a significant reduction in material handling, a better use of space and the efficiency of workflow (İnce & Taşdemir, 2024; Karaman et al., 2025). Similarly, in the food and bakery industry, research on MSMEs like Saramanta Homemade showed that through a workflow redesign through Systematic Layout Planning (SLP) and supply chain optimization, the company experienced significant improvements in moving distances, handling time, and cost involved in the process and the overall labor productivity and profitability increased (Setyaningrum et al., 2025). These findings are providing tangible proof that both the planning of the layout and the streamlining of workflow are key to performance within any operating space of manufacturing.

Further strengthening the advantages of integrated layout and workflow strategies are advanced technologies which include simulation software, AR/VR and the application of AI for optimization. Case studies of automotive assembly, warehouse management, and tool shop optimization have shown that simulation based modeling using Plant Simulation, Arena and AI-enabled decision-making proved to be highly effective in improving throughput, reducing cycle times, minimizing operating bottlenecks, and improving resources utilization (Malega, Daneshjo, & Štofková, 2025; Mojumder & Nuruzzaman, 2025; Hau, 2020). AR-based layout planning was demonstrated as an option for flexibility in the redevelopment of the production lines, which quickly reconfigures the machinery and workflow, but also simultaneously offers real-time visualization to managers (Hau, 2020; Lind et al., 2024). These empirical findings point at the importance of adopting the digital approach and/or AI-enabled solutions to achieve operational efficiency, especially within complex manufacturing systems.

Comparative evidence from different industries and locations shows substantial benefits in efficiency, cost reduction and improvement in throughput due to optimisation of facility layouts and work flows. For example, transport distance was reduced by more than a third in the hospital laundry services in Thailand, while the implementation of layout and workflow redesign led to improved cash-to-cash cycle times with increased productivity and lower labor costs in SMEs in Nigeria (Laomongkholchaisri et al., 2024; Setyaningrum et al., 2025). In warehouse and logistics management, slotting and robotics mechanisms powered by artificial intelligence increased order picking efficiency by even 40% and minimized the travel time by 30% (Tulli, 2023; Mojumder and Nuruzzaman, 2025). Collectively, these empirical studies highlight the use of facility layout planning combined with optimizing improved workflow, which is supported by modern technologies as a proven strategy for increasing production efficiency in both developed and developing economies such as Africa, and West Africa/Nigeria in particular.

2.5 Research Gap

Despite the huge volume of studies on facility layout planning and optimization of work flows, there are a number of gaps. Most of the studies have been focused on these dimensions independently and therefore there is a living gap where they mutually establish explicit relations as integrated frameworks that have explicitly linked layout and workflow

optimisation with the measurable actions of production efficiencies (Zuniga et al. 2020; Xu, X and Su 2024). While there is evidence from past studies of operational improvement in single sectors, few studies analyze the integration of spatial design and process efficiency and their combined impact on the throughput, cycle times, and of course, resource utilization. Additionally, there is little empirical evidence from SMEs and developing economies (including African economies such as Nigeria). Most case studies come from highly industrialized areas with an overabundance of technological infrastructure, that left a knowledge gap on the applicability and scalability of layout and workflow optimization methods in resource-constrained environments (Karaman et al., 2025; Setyaningrum et al., 2025). This underrepresentation of SMEs and developing country contexts limits the extent to which best practice can be generalized and policies and management understandings in these regions.

Furthermore, there is a significant gap in the research introducing digital tools, AI, and simulation-based methodologies for the integrated layout, workflow optimization methods for developing economies. While advanced technologies have shown significant efficiency improvements in warehouses, auto and food manufacturing industries, worldwide, their adoption, adaptation and the impact of performance in emerging markets is under explored (Hau, 2020; Mojumder & Nuruzzaman, 2025). Addressing these gaps is very important to present some evidences on strategies that can be used by manufacturing organisations in pursuit of operational excellence and the improvement of sustainable production efficiency, in the areas of Nigeria, West Africa and African larger reach.

2.6 Conceptual Framework of the Study

The conceptual framework of this study shows the correlation relationship between Facility Layout Planning (IV1) and Workflow Optimization (IV2) as the independent variable and Production Efficiency (DV) as the dependent variable. An optimized facility layout helps in minimizing unnecessary movement and handling costs and increases space utilization, while workflow optimization helps in effectively executing the tasks, addressing bottlenecks, and allocating resources (Tulli, 2023; Mojumder & Nuruzzaman, 2025). Together, these dimensions combine to have a synergistic effect that leads to increased throughput, reduced cycle time, improved labor productivity and overall operational efficiency in manufacturing systems. The framework reflects the expected outcomes in global, African, West African, and Nigerian context, emphasizing the strategic integration of the layout and workflow that contributes to the sustainable performance of production (Karaman et al., 2025; Setyaningrum et al., 2025; Xu, Xu, & Su, 2024).

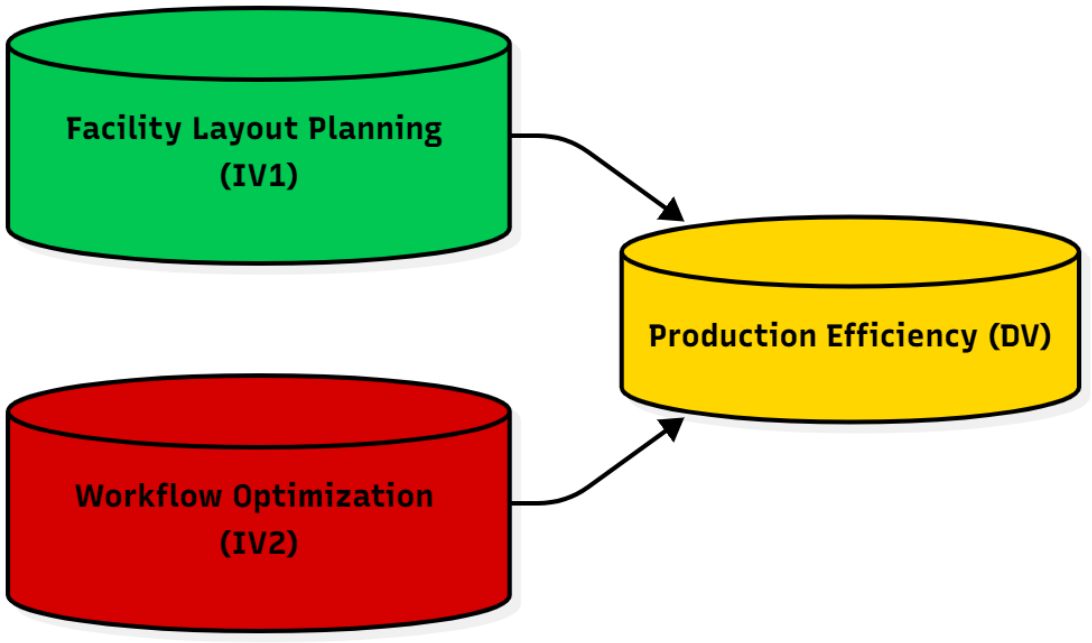

Figure 2.2: Conceptual Framework of Facility Layout and Workflow Optimization on Production Efficiency

Source: Developed by the author based on literature (Tulli, 2023; Mojumder & Nuruzzaman, 2025; Karaman et al., 2025; Xu, Xu, & Su, 2024).

The diagram shows that facility layout as well as the optimization of the workflow has a direct and positive influence on the efficiency of production. Facility layout makes a contribution which involves minimizing the physical movement, the costs of handling and optimizing the use of space, which is according to the principles of Resource-Based View (RBV). Continuing this, workflow optimization helps optimize the way that tasks are carried out, both in terms of bottleneck issues and applying lean principles - in line with principles of Lean Manufacturing and Theory of Constraints (TOC). Collectively, the framework shows a synergistic relationship in which operational resources (human, technological, and physical) are efficiently aligned to improve throughput, achieve a reduction in cycle times, and improve labor productivity. This integrated approach to the challenges highlights the significance of both spatial and process-oriented approaches to achieving sustainable production efficiency across manufacturing environments in the world including Africa and Nigeria.

3.0 Research Methodology

This research paper takes a conceptual research approach, during which attempts will be made to synthesize available literature and theoretical knowledge in providing a comprehensive understanding of the impact of facility layout and optimization of flow on production efficiency. As a conceptual paper, the methodology does not involve the collection of primary information or field experiments. Instead, it focuses on utilizing systematic literature review techniques based on empirical studies, case reports, and simulation-based research studies in the manufacturing industry, in and around the globe, Africa, West Africa, and Nigeria (Zubair et al., 2020; Xu, Xu, & Su, 2024; Mojumder & Nuruzzaman, 2025). This way the study has been able to find theoretical connections between the planning of the layout, optimization of flows and production performance. The selection of literature and industrial case examples is made according to clear criteria and made sure to be relevant and rigorous and applicable. Studies were

included if they concerned the layout design of facilities, optimum optimization of workflow, simulation-based analysis of efficiency and the integration of digital or AI-based tools in production systems (Tulli, 2023; Setyaningrum et al., 2025; Karaman et al., 2025). Both large scale and small-to-medium enterprises (SMEs) were taken into consideration, with special attention to manufacturing situations which are representative of context of operation, challenges of developing economies like Nigeria. The inclusion of case studies in footwear, food, automotive and warehouse industries enables a wide generalization of laid out and flow impacts in contexts with very different industrial settings. For analytical synthesis, the study uses the analysis method of a conceptual approach to bring together the findings of different sources in order to identify patterns, best practices, gaps in literature. This implies comparing the efficiency metrics of the methods, such as throughput, cycle time, labor productivity, waste reduction, and utilization of resources for different layout and workflow strategies (Malega, Daneshjo, & Štofková, 2025; Xu, Xu, & Su, 2024). Insights gained from simulation, AR/VR, and optimization techniques based on artificial intelligence are analyzed for the efficiency of production. The conceptual synthesis informs the proposed integrated framework, in which the concepts of facility layout and optimization of workflow connect directly to observable improvements in production performance, in order to provide a theoretical background for future empirical studies and applications.

4.0 Findings of the Study

1. Impact of Facility Layout on Operational Efficiency: Systematic facility layout design was found have significantly improved material handling, production lead time and overall operational efficiency in manufacturing enterprises both in global, African, West African and Nigerian production enterprises (Aliyu Mohammed, 2023; Xu, Xu, & Su, 2024; Karaman et al., 2025). Optimized layouts reduce wasteful movement, shorten the lines of flow and create more predictable production processes.

2. Impact of Workflow Optimization of Productivity: Workflow optimization, process mapping, lean tools (5S, VSM), and scheduling using simulation have a positive impact on labor productivity, resource use, and reduction of bottlenecks (Tulli, 2023; Mojumder & Nuruzzaman, 2025). Efficient workflows ensure that things are done in a timely manner, thereby leading to higher throughput and less waste within the organization.

3. Key Factors and Challenges in Implementation: An optimized facility layout and workflow in developing economies, especially Nigeria, are key issues of implementation which are dependent on factors such as management commitment, workmen's training, technology adoption, and ergonomic implication. Challenges include a shortage of financial resources, lack of infrastructure and low awareness of digital optimization tools (Setyaningrum et al., 2025; Mohammed & Sundararajan, 2023).

4. Role of Digital Tools and Simulation: Assignment of simulation software, AR/ VR visualization & AI based Workflow Management Technologies to optimize the decision while planning a facility layout and process optimization. Digital tools are able to provide predictive insights, allow for scenario testing, and contribute to the sustainable production performance (Malega, Daneshjo, & Štofková, 2025; Hau, 2020).

5. Practical Implications for Managers and Stakeholders: Integrating facility layout planning and workflow optimization with the capacity to deliver objective improvements in production efficiency such as improved production throughput, reduced cycle times, and improved use of resources. These findings provide manufacturing managers and policymakers with strategies they can implement to increase operational efficiency in a variety of manufacturing scenarios (Setyaningrum et al., 2025; Xu, Xu, & Su, 2024).

5.0 Recommendations of the Study

1. Best Practices for Facility: Layout Design Manufacturing enterprises are advised to proceed with the layout planning approaches such as SLP and ALDEP to make sure that layouts reduce

material handling costs and facilitate the circulation of production (Karaman et al., 2025; Laomongkholchaisri et al., 2024).

2. Workflow Management Strategies: Firms should implement all workflow optimization techniques, such as lean manufacturing tools, process mapping, and continuous improvement strategies, to improve labor productivity, reduce bottlenecks, and maximize the use of resources (Tulli, 2023; Mojumder and Nuruzzaman, 2025).

3. Technology Integration: Organizations are encouraged to take advantage of digital technologies, simulation software (Plant Simulation, Arena), and AI/AR-based optimization to design and test layouts and workflows before physically implementing them to save on trial-and-error costs (Hau, 2020; Malega, Daneshjo, & Štofková, 2025).

4. Sustainable Production Practices: When making layout and design for workflows, manufacturing managers should involve strategies for sustainable production that are environmentally and economically sustainable concerning energy-efficiency, waste-generation-reduced workflows and ergonomics for safety (Setyaningrum et al., 2025; Xu, Xu, & Su, 2024).

5. Guidance for SMEs and Policymakers: Policymakers and SME managers should promote capacity development processes, training programs, and supportive policy for technology adoption, improved digital literacy, and best practices implementation in manufacturing layouts and processes flowcharts especially within developing economies such as the Nigerian nation (Mohammed, 2023; Aliyu Mohammed, 2024).

REFERENCES

1. Achmad, H., & Santoso, S. (2025). *Redesign of production facility layout using systematic layout planning (SLP) method to improve operational efficiency at PT. XYZ. International Journal of Business and Applied Economics, 4*(5), 2879–2892.

2. Ali Naqvi, S. A., Fahad, M., Atir, M., Zubair, M., & Shehzad, M. M. (2016). *Productivity improvement of a manufacturing facility using systematic layout planning. Cogent Engineering, 3*(1), 1207296.

3. Aliyu Mohammed. (2023). *A study on HR strategies for managing talents in global perspective*. Paper submitted to the University of Belgrade, Technical Faculty in Bor, XIX International May Conference on Strategic Management (IMCSM23), Hybrid Event.

4. Aliyu Mohammed. (2024). *Investigating reskilling and up-skilling efforts in the information technology and software development sector: A case study of Kano State, Nigeria*. Paper presented at the International Conference on Paradigm Shift Towards Sustainable Management & Digital Practices: Exploring Global Trends and Innovations.

5. Andriani, D. P., Zamroni, M. H., Alesi, T. C., & Rahman, F. (2017, July). *The layout optimization of production process facilities in apple processing to improve productivity and sustainability SMEs*. In *2017 6th IEEE International Conference on Advanced Logistics and Transport (ICALT)* (pp. 184–188). IEEE.

6. Anjos, M. F., & Vieira, M. V. (2021). *Facility layout*. Cham, Switzerland: Springer International Publishing.

7. Balachandar, G. E., & Bhaskar Reddy, C. (2024, June). *Enhancing manufacturing efficiency: A strategic approach to facility layout optimization.* In *International Conference on Intelligent Manufacturing and Energy Sustainability* (pp. 115–125). Singapore: Springer Nature Singapore.

8. Ballais, J. H. V., Chua, F. S., Estera, J. A. C., Landicho, M. T. D., Mosuela, R. G., Paner, K. N. G., & Navarro, M. M. (2024). *Enhancing productivity by optimizing facility layout in a garment manufacturing company using ProModel simulation.*

9. Cabusas, E., Helis, C., Malonda, D., Paguio, A., Pangan, K., Perez, B., ... & Peralta, V. (2023). *Optimizing facility layout for enhanced productivity using Pro Model: A case study of a shoe manufacturing company in Marikina, Philippines*. In Proceedings of the 4th Asia Pacific International Conference on Industrial Engineering and Operations Management.

10. Dbouk, H. M., Ghorayeb, K., Kassem, H., Hayek, H., Torrens, R., & Wells, O. (2021). *Facility placement layout optimization. Journal of Petroleum Science and Engineering, 207*, 109079.

11. Gore, K. A. (2018). *Systematic efficiency improvement by optimizing plant layout using Witness simulation software* (Master's thesis, Rajarambapu Institute of Technology, Rajaramnagar).

12. GR, V., & CR, S. (2024). *Enhancing facility layout optimization: A performance analysis of genetic algorithm variants in dynamic facility layout problems*. IAENG International Journal of Computer Science, 51(11).

13. Haddou Amar, S., Abouabdellah, A., & El Ouazzani, Y. (2018). *Interactive facility layout problem: A bi-objective design.* International Journal on Interactive Design and Manufacturing (IJIDeM), 12(1), 151–159.

14. Halawa, F., Madathil, S. C., Gittler, A., & Khasawneh, M. T. (2020). *Advancing evidence-based healthcare facility design: A systematic literature review*. Health Care Management Science, 23(3), 453–480.

15. Hau, T. C. (2020). *Development of an augmented reality based facility layout planning and optimization* (Master's thesis, University of Malaya, Malaysia).

16. Ike, C. F., Barnaby, J., Aniegbuna, A., Ilouno, D., & Ibekwe, D. (2024). *Optimizing productivity: Spatial organization strategies for palm product processing factories in Nigeria.*

17. İnce, M. N., & Taşdemir, Ç. (2024). *Facility layout planning through the ALDEP method in the wooden cable reels industry.* Turkish Journal of Forestry, 25(1), 71–80.

18. Jasrotia, M. S., & Sengottaiyan, K. (2024). *SLP (Systematic Layout Planning) for enhanced plant layout efficiency*. *International Journal of Science and Research (IJSR), 13*(6), 820–827.

19. Junior, W. A., Azzolini, F. G. P., Mundim, L. R., Porto, A. J. V., & Amani, H. J. S. (2023). *Shipyard facility layout optimization through the implementation of a sequential structure of algorithms*. Heliyon, 9(6).

20. Kanbur, B. B., Suping, S., & Duan, F. (2020). *Design and optimization of conformal cooling channels for injection molding: A review.* The International Journal of Advanced Manufacturing Technology, 106(7), 3253–3271.

21. Karaman, Z., Elçin, B., Solak, K. D., Erdal, S. C., Kırkavak, N., & İç, Y. T. (2025). *Facility layout planning using ALDEP and SketchUp for a printing company*. International Journal on Interactive Design and Manufacturing (IJIDeM), 19(9), 6745–6771.

22. Khalilabadi, S. M. G., Roy, D., & de Koster, R. (2024). *Exploiting travel sequences to optimise facility layouts with multiple input/output points*. International Journal of Production Research, 1–29.

23. Kilari, S. D. (2025). *Use of artificial intelligence into facility design and layout planning work in manufacturing facility*. *European Journal of Artificial Intelligence and Machine Learning, 4*(2), 27–30.

24. Kovács, G. (2017). *Layout redesign for cost reduction and efficiency improvement*. Journal of Applied Economic Sciences, 12(49), 663–670.

25. Kovács, G., & Kot, S. (2017). *Facility layout redesign for efficiency improvement and cost reduction*. *Journal of Applied Mathematics and Computational Mechanics, 16*(1).

26. Kumar, M. A., Mohammed, A., Raj, P., & Sundaravadivazhagan, B. (2024). Entrepreneurial strategies for mitigating risks in smart manufacturing environments. In *Artificial Intelligence Solutions for Cyber-Physical Systems* (pp. 165–179). Auerbach Publications.

27. Laomongkholchaisri, N., Arandorn, N., Wangsaward, T., & Musikanit, S. (2024). *Plant layout and design of central supply laundry department: A case study of a hospital in Songkhla Province.* Engineering and Technology Horizons, 41(4), 410406–410406.

28. Lawal, T. O., Abdulsalam, M., Mohammed, A., & Sundararajan, S. (2023). Economic and

environmental implications of sustainable agricultural practices in arid regions: A cross-disciplinary analysis of plant science, management, and economics. *International Journal of Membrane Science and Technology*, *10*(3), 3100–3114. https://doi.org/10.15379/ijmst.v10i3.3027

29. Leiber, D., Eickholt, D., Vuong, A. T., & Reinhart, G. (2022). *Simulation-based layout optimization for multi-station assembly lines*. Journal of Intelligent Manufacturing, 33(2), 537–554.

30. Lin, Q., & Wang, D. (2019). *Facility layout planning with SHELL and fuzzy AHP method based on human reliability for operating theatre*. Journal of Healthcare Engineering, 2019(1), 8563528.

31. Lind, A., Hanson, L., Högberg, D., Lämkull, D., Mårtensson, P., & Syberfeldt, A. (2024). *Integration and evaluation of a digital support function for space claims in factory layout planning.* Processes, 12(11).

32. Ludwika, A. S., Shalehah, M. A., Mohamad, R. R. A., Oktavia, A. T., Normasari, N. M. E., Tho, N. H., & Rifai, A. P. (2024). *Facility layout planning of sheet metal working industry using metaheuristics*. Spektrum Industri, 22(2), 163–178.

33. Malega, P., Daneshjo, N., & Štofková, K. R. (2025). *Optimization of manufacturing plant layout by practical application of plant simulation.* Advances in Science and Technology: Research Journal, 19(9).

34. Masoud, S., Chowdhury, B. D. B., Son, Y. J., Kubota, C., & Tronstad, R. (2019). *Simulation-based optimization of resource allocation and facility layout for vegetable grafting operations*. Computers and Electronics in Agriculture, 163, 104845.

35. Mohammed, A. (2023). Analyzing global impacts and challenges in trade management: A multidisciplinary study. *Economics, Commerce and Trade Management: An International Journal (ECTU), 3*.

36. Mohammed, A. (2023). Navigating the digital marketplace: Strategies for entrepreneurship in electronic commerce. *Computer Applications: An International Journal (CAIJ), 10*(3/4). Retrieved from https://airccse.com/caij/papers/10423caij06.pdf

37. Mohammed, A. (2023). Strategic utilization of management information systems for efficient organizational management in the age of big data. *Computer Applications: An International Journal (CAIJ), 10*(3/4). Retrieved from https://airccse.com/caij/papers/10423caij02.pdf

38. Mohammed, A., & Sundararajan, S. (2023). Analyzing policy challenges in the financial sector: Implications for effective financial management. In *Digitalization of the Banking and Financial System* (pp. 32–43). ISBN: 978-93-91772-80-2.

39. Mohammed, A., & Sundararajan, S. (2023). Emerging trends of business transformation. *MSNIM Management Review, 1*, 36–44.

40. Mohammed, A., & Sundararajan, S. (2023). Exploring the dynamic interplay between startups and entrepreneurship: A conceptual analysis. In *Digital Startup: A Multidisciplinary Approach in Technology and Sustainable Development* (pp. 1–7). ISBN: 978-93-93376-66-4.

41. Mohammed, A., Jakada, M. B., & Lawal, T. O. (2023). Examining the impact of managerial attitude on employee performance and organizational outcomes: A conceptual analysis. *IJBRE – International Journal of Business Review and Entrepreneurship, 4*(1), 1115–9146.

42. Mohammed, A., Shanmugam, S., Subramani, S. K., & Pal, S. K. (2024). Impact of strategic human resource management on mediating the relationship between entrepreneurial ventures and sustainable growth. *Serbian Journal of Management.* https://doi.org/10.5937/IMCSM24044M

43. Mojumder, M. U., & Nuruzzaman, M. (2025). *AI-driven optimization of warehouse layout and material handling: A quantitative study on efficiency and space utilization.* Review of Applied Science and Technology, 4(2), 233–273.

44. Muhammed, A., Sundararajan, S., & Lawal, T. (2022). The effect of training on the performance of small and medium-sized enterprises (SMEs) in Kano metropolis. *Seybold Report, 17*(6).

45. Munavalli, J. R., Singh, S. K., & Oruganti, S. K. (2025). *Adaptive layout redesign and patient flow optimization for enhanced patient care: Current state and future directions.* SPAST Reports, 2(1).

46. Nordin, N. N., Ab Razak, R., & Marthandan, G. (2023). *A unique strategy for improving facility layout: An introduction of The Origin algorithm*. Sustainability, 15(14), 11022.

47. Nurkamila, H. H., Sharone, J. R., Setyawati, T. I. B., Hanifah, Y., Nurcahyo, R., & Nurdini, A. (2024). *Facility layout planning optimization in a family restaurant using systematic layout planning and ergonomic approach*. *IEOM Society International, 6*.

48. Pérez-Gosende, P., Mula, J., & Díaz-Madroñero, M. (2020). *Overview of dynamic facility layout planning as a sustainability strategy*. *Sustainability, 12*(19), 8277.

49. Peron, M., Fragapane, G., Sgarbossa, F., & Kay, M. (2020). *Digital facility layout planning. Sustainability, 12*(8), 3349.

50. RazaviAlavi, S., & AbouRizk, S. (2017). *Site layout and construction plan optimization using an integrated genetic algorithm simulation framework*. *Journal of Computing in Civil Engineering, 31*(4), 04017011.

51. Riesener, M., Schukat, E., Curiel-Ramirez, L. A., Schäfer, N., & Valdez-Heras, A. (2024). *Development of a VR-based digital factory planning platform for dynamic 3D layout editing*. Procedia CIRP, 130, 419–426.

52. Roca-Limache, C. J., Quispe-León, D. M., & Tupia-De-La-Cruz, E. L. (2025). *Designing a lean production model using 5S and systematic layout planning for efficiency in footwear manufacturing: A case study*.

53. Sabra, M., & Sabra, A. (2023). *Optimization of facility layout planning problems in manufacturing: A simulation-based approach in an Industry 4.0 environment.*

54. Sadar, M. P., Rajmore, K. G., Rodge, M. K., & Kumar, K. (2023). *Digital manufacturing approach for process simulation and layout optimization*. *Materials Today: Proceedings, 74*, 642–649.

55. Setyaningrum, R., Erthamevia, F. K., Febriana, S. D., & Setyanti, A. V. I. (2025). *Optimization of production layout, production process, and supply of materials to increase work productivity in Saramanta homemade*. *OPSI, 18*(1), 173–188.

56. Setyaningrum, R., Erthamevia, F. K., Febriana, S. D., & Setyanti, A. V. I. (2025). *Optimization of production layout, production process, and supply of materials to increase work productivity in Saramanta Homemade.* OPSI, 18(1), 173–188.

57. Shafira, A., Putri, D. M., Aisha, D. L., Ghassani, S., Nurcahyo, R., & Habiburrahman, M. *Redesign of facility layout and material handling in a cake production factory using systematic layout planning*.

58. Shanmugam Sundararajan, S., Rajkumar, T., Senthil Kumar, T., Mohammed, A., & Prince Martin, V. (2024). An analytical study on factors influencing individual investors' investment decisions on selecting private commercial banks at Kano City in Nigeria. *European Chemical Bulletin, 12*(1), 3706–3717. https://doi.org/10.31838/ecb/2023.12.s1-B.372

59. Sundararajan, N., & Terkar, R. (2022). *A roadmap to improving productivity in a fastener manufacturing unit by process optimization using ARENA.* Materials Today: Proceedings, 62, 1017–1025.

60. Sundararajan, S., & Mohammed, A. (2022). Entrepreneurial opportunities for women. In *Proceedings of the Conference on Gender Equality and Women Empowerment*. *European Journal of Humanities and Educational Advancements, Special Issue 1*, 112–115.

61. Sundararajan, S., & Mohammed, A. (2023). Evaluation of teachers – History to current era. *Samzodhana – Journal of Management Research, 13*(2). Retrieved from http://eecmbajournal.in

62. Sundararajan, S., Mohammed, A., & Lawal, T. (2023). Role of human resource management in

the post COVID-19 era: Experiential study. *Bio Gecko: A Journal for New Zealand Herpetology, 12*(2).

63. Sundararajan, S., Mohammed, M. A., & Senthil Kumar, S. (2022). A perceptual study on impact of agile performance management system in the information technology companies. *Scandinavian Journal of Information Systems, 34*(2), 3–38.

64. Süße, M., Ahrens, A., Richter-Trummer, V., & Ihlenfeldt, S. (2023, March). *Assisted facility layout planning for sustainable automotive assembly*. In *Future Automotive Production Conference 2022* (pp. 173–188). Wiesbaden: Springer Fachmedien Wiesbaden.

65. Tulli, S. K. C. (2023). *Warehouse layout optimization: Techniques for improved order fulfillment efficiency*. International Journal of Acta Informatica, 2(1), 138–168.

66. Xu, L., Xu, B., & Su, J. (2024). *Facilities layout design optimization of production workshop based on the improved PSO algorithm*. IEEE Access.

67. Yang, Z., & Lu, W. (2023). *Facility layout design for modular construction manufacturing: A comparison based on simulation and optimization. Automation in Construction, 147*, 104713.

68. Zhang, M., Batta, R., & Nagi, R. (2011). *Designing manufacturing facility layouts to mitigate congestion*. *IIE Transactions, 43*(10), 689–702.

69. Zúñiga, E. R., Moris, M. U., Syberfeldt, A., Fathi, M., & Rubio-Romero, J. C. (2020). *A simulation-based optimization methodology for facility layout design in manufacturing*. IEEE Access, 8, 163818–163828.

Zupan, H., Herakovic, N., Zerovnik, J., & Berlec, T. (2017). *Layout optimization of a production cell*. *International Journal of Simulation Modelling, 16*(4), 603–616.