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Impact of Production Process, Design and Line Balancing on Operational Performance

Abubakar Bashir Dandawaki[1], Umar Bashir Dandawaki[2], Aliyu Mohammed[3]

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

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***Corresponding Author:** Abubakar Bashir Dandawaki

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Abstract **Original Research Articles**

Manufacturing sector is an imperative element in the process of ensuring economic growth, yet most organizations struggle to achieve optimum operation performance based on inefficiency in production processes, inadequate design, and imbalanced production lines. This theoretical research paper examines the implications of operations inside the standardization of the production processes, the optimization of production design and line-balancing and its effects on the operation of manufacturing companies. The paper addresses certain significant issues in research studies such as process standardisation in efficiency and quality; the role of production design in utilizing resources and optimising workflow the role of line balancing on throughput, labour productivity and the minimization of bottlenecks. Based on a conceptual research approach, the research is informed by second hand data in terms of peer-reviewed journals, books, historical documents and industry reports that help to synthesize the data of the past empirical studies. Literature analysis shows that the improvements areas in terms of production processes, integration of the optimized design, and the effective line balancing all enhance productivity, the cycle time decrease, the level of waste elimination, and encourage sustainable operation performance. Based on these findings, the study suggests that manufacturing managers should use integrated production strategies that coordinate production processes, design and workflow management to achieve operational excellence. The study concludes that a holistic management approach for production process management and design, as well as line balancing is important to the local and global manufacturing competitiveness.

Keywords: Production Process, Production Design, Line Balancing, Operational Performance, Manufacturing Efficiency.

1.0 Introduction

1.1 Background of the Study

The manufacturing sector is well-known for being an industry that plays an important role in economic growth, job creation and industrial development all over the world. Efficient production processes, production design strategy and efficient line balancing are key factors affecting improved performance in operations, productivity, quality, cost efficiency and customer satisfaction (Kaplan & Cooper, 1998; Krafcik, 1988). Across the world, companies have pursued lean production systems, Total Quality Management (TQM) and other sophisticated forms of operation in order to optimise resources, minimise wastage and gain sustainable competitive advantage (Cua, McKone, & Schroeder, 2001; Prajogo & Olhager, 2012). Globally the adoption of advanced production practices and systems of performance measurement has changed the landscape of operational management. Studies indicate that current leading firms in the global manufacturing, such as Siemens, Hewlett-Packard and Procter & Gamble, use integrated production processes, development of line balancing and continuous improvement to drive efficiency, quality and profitability (Kaplan & Cooper, 1998; Krafcik, 1988). Moreover, the tools for measuring performance like Balanced Scorecard have been implemented in many governments of the world and used to align the operational activities with the strategic objectives and improve decision making in the complex production environment (Kaplan & Norton, 1996; Norreklit, 2000).

In Africa, the manufacturing sector has unique challenges that involve poor technological adoption, skills gap, and infrastructural challenges, which affects the efficiency and performance of the manufacturing sector (Aliyu, 2023; Gunasekaran, Patel, & McGaughey, 2004). However, studies indicate that organizations with structured production processes, maximum workflow design, and line balancing methods can continue with a high level of productivity and operational results even in resource-limited situations (Vijay and Prabha, 2021; Ariffin and Khaled, 2016). Upon western Africa, the manufacturing companies have issues in west-Africa, including access to power supply, modern equipment, and disjointed supply chains, which impact the sustained performance (Mohammed & Sundararajan, 2023; Rai, Patnayakuni, and Seth, 2006). However, it is indicated by research conducted in the region that companies using lean manufacturing principles and standard operating procedures along with balancing practices of a line - these approaches allow optimization of cycle times, waste, and increased efficiency in the production process in general - are ultimately in a good position to receive the desired results (Vijay and Prabha, 2021; Prajogo and Olhager, 2012). Industrial sector in Nigeria has also experienced efforts to modernize the production process particularly through the introduction of line balancing, process optimization and production design systems of more effective operation (Mohammed, 2023; Mohammed and Sundararajan, 2023). Empirical evidence underscores the fact that firms which strategically concentrate on improvement of production processes and resource utilization experience higher productivity and reduced operation cost with improved quality outcomes being necessary for maintaining competitiveness in local and global markets (Aliyu, 2024; Mohammed, Jakada, & Lawal, 2023).

Despite such advancements, operational inefficiencies still prevail in the form of unbalanced production lines, inefficient workflow design and production resource utilization. Therefore, the need to study the effect of production process, design, and line balancing on the operation performance in a Nigerian manufacturing setting for practitioners and policy makers has become very evident.

1.2 Problem Statement

Operational performance in manufacturing organizations is increasingly being realized as a vital determinant of competitiveness, profitability and sustainability. Despite the improvement in production technology, process design, and measurement system of performance, many manufacturing firms still face inefficiency in production, including unbalanced production line, extended cycle times, failure in resources, and inconsistent quality in products (Kaplan & Cooper, 1998; Krafcik, 1988). These inefficiencies are more common in developing economies because infrastructural limitations, low adoption in the application of modern production techniques, and workforce skills limit the full potential of operational improvements (Aliyu, 2024; Gunasekaran, Patel, & McGaughey, 2004). Globally, key companies with and putting in place well-structured production processes, lean manufacturing principles, and effective line balancing techniques not only attain superior working processes, but also have fewer waste and more effective flow and quality (Cua, McKone, & Schroeder, 2001; Vijay & Prabha, 2021). However, there is evidence to suggest that adoption of such practices is not uniform and many organizations do not implement all production design improvements and translate them into measurable performance improvements (Prajogo & Olhager, 2012; Ariffin & Khaled, 2016).

In the African context, especially for West Africa and Nigeria, manufacturing firms are facing other challenges like the inconsistent supply of power, poor technological infrastructure, and disjointed supply chains that contribute to the inefficiency of production and have a negative impact on that company's operational results (Mohammed & Sundararajan, 2023; Rai, Patnayakuni, & Seth, 2006). Empirical studies suggest that although lean production, standard operating procedures (SOPs), and line balancing may significantly improve productivity and quality, their use is limited to systematic implementation and researches have not found the integrated effects of the three techniques on operational performance in manufacturing firms in Nigeria (Vijay and Prabha, 2021; Mohammed, Jakada, and Lawal, 2023). Therefore, despite the importance of the production processes, design, and line balancing, there is a disconnect regarding the extent to which these factors can collectively affect the operational performance in the manufacturing setting in Nigerian context. This gap weakens the capacity of manager and policymaker to design effective interventions to optimize production systems, increase efficiency and assuage competitive advantage.

1.3 Significance of the Study

The importance of studying the effect of production process, design and the balancing of line on the operational performance is multilevel from the theoretical, managerial and practical aspect. Understanding these relationships is critical to improving the performance of organizations seeking to achieve operational excellence, increased levels of productivity, and competitiveness on the global and personal manufacturing landscape (Kaplan and Cooper, 1998; Krafcik, 1988). It has been established worldwide that the manufacturing businesses that embrace systematic production systems, line balancing methods, and lean operation strategies have steadily improved in quality and efficiency and profitability (Cua, McKone, and Schroeder, 2001; Vijay and Prabha, 2021). The lessons learned in these best practices are a reference point to the emerging economies and also incorporates the strategies of designing production in a structured way and process standardization as a means of providing a framework of measurable performance results. In Africa and West Africa in particular, manufacturing industries are experiencing some strange operation challenges like lack of technological gap, lack of skill in workforce, long distribution chains among others which is the problem in making the production better to operational better (Aliyu, 2024; Mohammed & Sundararajan, 2023). This research is fairly useful in the sense that it contextualises the concepts of production process and line balancing tactic in such types of operational constraints, developing a system that would result in enhanced efficiency, less wastage and general operation of the plant.

Contemporary mode of production is still sporadic in Nigeria with numerous companies struggling to establish the standard operating procedures, production lines equilibrium or production design upgrades into daily transactions (Prajoko and Olhager, 2012; Ariffin and Khaled, 2016). This study contributes to a greater comprehension of the overall effect of production processes, design and line balancing on operation performance by systematically exploring the above factors. The findings will probably enlighten applying the resources by the manufacturing managers to maximize the cycle time, product quality, and generation of decent competitiveness. Academically, the research work has accomplished something in literature because the study has yielded empirical results on the combined influence of production process, design and line balancing on the operational results in the manufacture plant of Nigeria. In practice, it provides operational data to managers, engineers and policy makers to develop interventions that are optimal in operation effectiveness, supply chain performances and economic growth (Gunasekaran, Patel, and McGaughey, 2004;

Mohammed, Jakada, and Lawal, 2023).

1.4 Research Objectives

The main aim of the study is to analyze how the production process, design and line balancing influence the performance of operations of manufacturing organizations. In particular, the study will attempt to:

1. To determine the effect of the standardization of production processes on the operational performance measures, which are efficiency, quality, and productivity.
2. To assess the presentation of production design advancements in improving the working process, lessening the cycle time, and upgrading the resources employed.
3. To explore the impact of line balancing on the overall operation performance such as throughput, labor usage, and elimination of bottlenecks.
4. To investigate the joint effect of production process, design and line balancing on sustainable operations performance of manufacturing environments.
5. To give practical suggestions that can be adopted by manufacturing managers in order to have an effective production and operation strategies that would result in improved performances in local (Nigeria, West Africa) and international environments.

1.5 Research Questions

1. How does standardization of the production process influence operational performance in manufacturing firms?
2. To what extent do improvements in production design contribute to enhanced operational efficiency and productivity?
3. What is the effect of line balancing on key operational performance indicators such as throughput, labor utilization, and bottleneck reduction?
4. How do production process, design, and line balancing collectively impact sustainable operational performance?
5. What strategies can manufacturing managers adopt to optimize production processes and line balancing for improved operational outcomes in Nigeria and similar developing economies?

2.0 Literature Review

2.1 Conceptual Review

2.1.1 Production Processes

Definition and Evolution of Production Processes in Manufacturing

Production processes refer to the ordered series of activities that are used in the transformation of raw materials into finished goods. Over the decades, manufacturing has progressed from older, labor-intensive methods to extremely automated technology driven systems. Early production systems were oriented to mechanization and assembly line efficiency out of Fordistic inspiration focused on standardization and mass production (Krafcik, 1988). The evolution further continued with the introduction of lean manufacturing principles which focused on efficiency, waste reduction and continuous improvement (Vijay & Prabha, 2021). Extending to global manufacturing scenarios, these practices have been vital in enhancing competitiveness, the efficiency of operations, and the quality of the products (Kaplan & Cooper, 1998).

Lean Manufacturing and Waste Elimination Strategies

Lean manufacturing is a school of thought in manufacturing that focuses on waste reduction and maximum value creation throughout the value chain. Some of the forms of waste in production include overproduction, waiting time, transportation, unnecessary transportation, excessive inventory and defects (Slack, Chambers, & Johnston, 2010). By adopting lean strategies like standardisation of work, continuous improvement (Kaizen) and just-in-time production, firms can make a significant progress in boosting productivity, lowering costs and improving performance (Vijay & Prabha, 2021; Krafcik, 1988). In the African & Nigerian manufacturing arena, lean implementation is manifesting itself as a core factor to enhancing efficiency within industrial areas such agro-processing, electronics and automotive assembly (Mohammed, Jakada, & Lawal, 2023; Aliyu, 2024).

Process Standardization and Optimization Methods

Process standardization refers to the process of creating unified procedures and best practices to achieve uniformity, efficiency, and quality in the production operations (Ariffin and Khaled, 2016). Optimization techniques such as time and motion study, line balancing, and workflow analysis allow for identifying bottlenecks in the operation and optimizing to satisfy the requirements according to pulse time and demand of the customer (Vijay & Prabha, 2021). Studies have shown that the mean of standardisation and optimisation of the production process has led to the increase of throughput, decrease the cycle time, and decrease the operational costs (Kaplan & Cooper, 1998; Prajogo & Olhager, 2012). In Nigerian manufacturing companies, process standardization is still hindered by problems like lack of good infrastructure, non-availability of good skilled labor, inconsistent adherence to the best practices in the world etc. but process improvement in a structured way can improve effectiveness of the operations significantly (Mohammed, Sundararajan, & Lawal, 2023).

Role of Total Quality Management (TQM) and Continuous Improvement

Total Quality Management (TQM) is a total approach to integration of quality principles into all aspects of the production process and ensures that products and services meet customer expectations consistently. TQM stresses employee involvement, process ownership, and problems solving in an organized manner for producing consistent improvement in quality and operational effectiveness (Cua, McKone, & Schroeder, 2001; Appelbaum, 2000). In global manufacturing environments, TQM has been associated with a reduction in defects, increased customer satisfaction, and increased financial performance (Kaplan & Cooper, 1998). TQM is closely allied with lean, where the philosophy of continuous improvement (Kaizen) promotes continuous small improvements building up to significant increased efficiency (Vijay & Prabha, 2021). Regarding the African and Nigerian manufacturing sectors, there exists a prospect of addressing some of the problems that emerge like an irregular and erratic product quality, high defect, insufficient standardization procedure, etc., which can be addressed through the TQM systems to improve the overall functional performance (Mohammed, Jakada, & Lawal, 2023; Aliyu, 2024).

Use of Technology and Automation in Production Processes

Technology combined with automation has transformed the past production systems, which are highly efficient, agile and responsive. Automated production line, robotics, computer-aided manufacturing (CAM), and real-time monitoring systems enable the manufacturer to enhance preciseness, minimize human error, and have some uniformity in the product quality (Huang, Liu, Mokasdar, and Hou, 2013; Kaplan and Norton, 2003). Technological adoption in the developed manufacturing centres allows predictive maintenance and energy saving and assures ideal utilisation of resource distribution (Rai, Patnayakuni, & Seth, 2006). For the developing countries such as Nigeria, the adoption of technology is also being gradually seen as a strategic enabler for achieving competitive advantage in the market despite the existing factors that still pose significant barriers, including the high initial cost of implementing technologies, limited technical skills, and lack of infrastructure (Mohammed 2023; Aliyu 2024). Implementing technology-driven production processes can also cultivate lean goals by reducing waste, producing a faster cycle-time, and allowing for data-driven decision-making.

Metrics for Assessing Process Performance

Effective measurement is important in assessing efficiency of production and pinpointing areas of improvement. Some important performance measures in the production processes include:

- **Cycle Time:** The total time which is required to complete a product from beginning to end. Shorter cycle times imply that higher efficiency and responsiveness to customers (demand) (Vijay & Prabha, 2021).
- **Throughput:** The quantity of the products obtained in a certain period that shows the production capacity of the system to satisfy demand Krafcik, 1988; Prajogo and Olhager, 2012.
- **Downtime:** Downtime is the time when machines or production lines cannot function normally due to maintenance, breakdown or inefficiencies. Minimizing downtime is important in ensuring consistent output and lowering operational cost (Ariffin & Khaled, 2016).

Performance metrics are used as diagnostic tools that help in optimizing processes, lines, and integrating technology. Organizations that systematically monitor such measures are better able to make improvements, to match operation with strategic goals and to maintain competitive advantage in the global and local manufacturing world (Kaplan & Cooper, 1998; Cua, McKone, & Schroeder, 2001). In the Nigerian manufacturing firms, the adoption of performance metrics has come up to increasingly central to the operational planning of the firms as this have enable them benchmark the efficiency, reduce wastage, and enhance productivity of the firm.

2.1.2 Production Design

Concept and Principles of Effective Production Design

Production design is the planning and structuring of the manufacturing process, systems and flow of activities to achieve optimal efficiency, quality and overall performance of the product manufacturing process. Effective production design is based on principles that have standardization, modularity, flexibility, and adaptability to changing market demands (Drucker, 1990; Slack, Chambers, & Johnston, 2010). Globally, companies that implement advanced methods of production design have achieved the goals of increased throughput, less waste and greater product quality by aligning production processes with organizational goals (Kaplan & Norton, 2003; Krafcik, 1988). In the African and West African context, the optimal production design is a key differentiator that enables manufacturers to participate in regional and international markets in a different economic system despite constraints such as resource scarcity and inadequate technological infrastructure (Mohammed, Sundararajan, & Lawal, 2022).

Importance of Workflow Layout, Machine Allocation, and Ergonomics

Workflow layout is one of the pillars of the production design, because it defines the order of operations, materials movements, and the relations between workers and machines. An optimized layout helps cut down bottlenecks, material handling, and lean manufacturing goals (Vijay & Prabha, 2021; Ariffin & Khaled, 2016). Strategic sorting of machines guarantees that resources are placed to ensure maximum utilization, minimum idle time and minimum downtime. Ergonomics on the other hand deals with physical as well as cognitive interaction between human operators and machinery in order to reduce fatigue, errors and workplace injuries (Appelbaum, 2000). Globally the best practices in production design combine lean principles, production modules, and human-centered design layouts to promote operational efficiency (Kleindorfer, Singhal, & Van Wassenhove, 2005). In Nigeria, the process of optimising the workflow, machine assignment, and ergonomics may improve productivity in manufacturing plants especially in SMEs and industrial clusters where resource limitations are common (Mohammed, 2023; Aliyu, 2024).

Design for Manufacturability and Cost Efficiency

Design for Manufacturability (DFM) is an approach that combines product design and manufacturing capabilities that will minimize production complexity, cost, and waste. By taking the manufacturability of products into account early on in the design stage, organizations can prevent the need to redesign products, conserve material consumption, and simplify the assembly process (Braungart, McDonough, & Bollinger, 2007; Huang et al., 2013). Cost efficiency is even added by modular designs, standardized components and flexible production systems that permit multiple product variants to be produced without significant reconfiguration (Kaplan & Cooper, 1998). For manufacturing firms in West Africa and Nigeria, the DFM and cost-driven production design strategies can help to boost competitiveness; lower production costs, improve scalability, and reduce lead times of production for delivery to the market (Mohammed, Shanmugam, Subramani, & Pal, 2024).

Integration of Design with Process Improvement Initiatives

The production design can be maximized when it is intertwined with the ongoing encouragement of process improvements and additions, such as the Lean Manufacturing, Total Quality Management (TQM) and Kaizen (Vijay and Prabha, 2021; Kaplan and Cooper, 1998). Matching design to improvement efforts ensures that both workflows, equipment layouts, and production methods will be continually improved so that waste is reduced, variability is decreased, and the overall efficiency of production is increased. Worldwide, organizations that incorporate design into continuous improvement programs have reported improvements in performance, reduced defect levels and consistent readiness to changing market conditions (Krafcik, 1988; Cua, McKone, & Schroeder, 2001). In West Africa and Nigeria, this integration is instrumental in overcoming some challenges, such as resource constraints, supply chain disruptions, workforce skills, which makes firms to remain competitive despite improving production reliability, production reliability and product quality (Mohammed, 2023; Aliyu, 2024).

Role of Simulation and Digital Tools in Design Optimization

The use of simulation and digital tools within production design has become a best worldwide practice for achieving a more efficient workflow, machine allocation and process sequence. Computer-aided design (CAD), digital twins and simulation software tools enable manufacturers to model production scenarios, detect bottlenecks and predict performance outcomes without affecting actual operations (Huang, Liu, Mokasdar, & Hou, 2013; Braungart, McDonough, & Bollinger, 2007). Digital tools allow you to test the alternatives of layout, distribution of resources and process changes in a small way, economical feedback, and more speed for decision making. In developing countries such as Nigeria, ample scope for the effective use of simulation and digital tools can be leveraged to improve the performance of operations by increasing the precision of operations, lowering downtime, and supporting data-dependence in production planning and scheduling (Mohammed, Shanmugam, Subramani, & Pal, 2024; Vijay & Prabha, 2021).

2.1.3 Line Balancing

Definition and Objectives of Line Balancing in Manufacturing Systems

Line balancing describes the systematic distribution of tasks between workstations in a production line to achieve an even distribution of workload, minimise idle time and streamline production with demand (Vijay & Prabha, 2021; Krafcik, 1988). The main goal of line balancing is to ensure smooth flow of materials and operations, minimizing bottlenecks and excessive waiting times, and variability in material output of operations. Globally, line balancing is known as a very important aspect of lean and flexible manufacturing systems as it directly affects the productivity, quality, and the capability to meet the مليون requirement (Cua, McKone, & Schroeder, 2001; Kaplan & Cooper, 1998). In the context of West Africa and Nigeria where manufacturing is subject to challenges such as equipment challenge, workforce skill gap and supply chain disruption, judicious line balancing assists organizations to optimize limited resources and enhance operational reliability (Mohammed, 2023; Aliyu, 2024).

Techniques for Balancing Workload across Operations

Several techniques are used to achieve effective line balancing such as the use of time studies, video based observations, precedence diagrams, heuristic algorithms (Vijay & Prabha, 2021; Slack, Chambers, & Johnston, 2010). Time studies are used to see what the critical path and task durations are, whereas precedence diagrams represent the graphical sequence of tasks and feasible dependencies. Heuristic methods support the decision process in task allocation to workstations for better efficiency such as the largest candidate rule or Kilbridge-Wester method. In addition, combining digital tools, simulation models, and software-based scheduling will help to optimize the allocation of tasks within complex manufacturing environments (Huang, Liu, Mokasdar, & Hou, 2013; Rai, Patnayakuni, & Seth, 2006). These techniques are taken together to ensure that production lines are more efficient at working to nearer takt time, idle capacity is minimised and cycle variability is reduced.

Impact of Line Balancing on Cycle Time, Productivity, and Operational Efficiency

There is a direct and measurable effect in operational performance as a function of efficient line balancing. By evenly distributing workloads, manufacturers can reduce cycle time and increase throughput and improve overall productivity (Vijay & Prabha, 2021; Krafcik, 1988). Operational efficiency increased as bottlenecks get eliminated, utilization of machines is increased and idle time of employees decreased. Research shows organizations that tap the benefits of systematic line balancing approaches, especially when integrated with lean manufacturing practices as well as TQM, enjoy improved product quality, superior on-time delivery, and cost-effective production (Cua, McKone, & Schroeder, 2001; Kaplan & Cooper, 1998). In developing economies like Nigeria, making good use of line balancing could also help manufacturing companies remain competitive regardless of the somewhat scarce resources to meet production quotas so that output matches the domestic and regional market demands (Mohammed, Shanmugam, Subramani, & Pal, 2024; Aliyu, 2024).

Relationship between Line Balancing and Takt Time

Line balancing and takt time cannot be separated from each other in manufacturing systems. Takt time is the speed at which products must be produced in order to meet customer demand and can be calculated by dividing the available production time by the required output (Vijay & Prabha 2021; Krafcik 1988). Effective line balancing keeps the workload at each work station in line with the takt time; any bottlenecks and idle time or overproduction are avoided. By pairing task allocation with the takt time, manufacturing companies will be able to attain a constant flow, maximize the use of resources, and sustain several constant production rates. In lean manufacturing world, this alignment helps to support just in time type of production and to reduce work in progress inventories and boost operations efficiency in general (Slack, Chambers, & Johnston, 2010; Cua, McKone, & Schroeder, 2001).

Case Studies of Successful Line Balancing Implementations

Several case studies on the global and regional level illustrate the positive plea to line balancing around the operations performance. For example, Vijay and Prabha (2021) constructed a research paper on cells of the CNC machine in windmill gearbox manufacturing plant which was applied standard operating procedures (SOPs), time studies, and line balancing techniques which help to decrease the cycle time and increase the production. Similarly, the lean production system by Toyota is an example of how systematic line balancing in conjunction with continuous improvement and workflow standardization result in higher quality, increased speed of production and lower operation costs (Krafcik, 1988; Kaplan and Cooper, 1998). In the West African setting, the adoption of line balancing among manufacturing firms in Nigeria in tandem with lean practices and TQM led to increase in throughput, reduced bottleneck, and alignment of demand according to market for that product (Mohammed, 2023; Aliyu, 2024). These examples point out how strategic line balancing if done correctly, can be a critical driver in achieving operational excellence and sustainable competitive advantage.

2.1.4 Operational Performance (DV)

Concept and Dimensions of Operational Performance

Operational performance: Resources, capabilities, human resources, and information systems are all involved in operational performance. It includes many dimensions such as productivity, quality, flexibility, cost management and delivery reliability (Slack, Chambers, & Johnston, 2010; Kaplan, 1983). Globally, organizations whose operations are best optimized are in a better position to compete in the dynamic market as improved performance directly relates to profitability, and also sustainability and customer satisfaction (Kaplan & Cooper, 1998; Prajogo & Olhager, 2012). In Africa, and Nigeria and West Africa in particular, resources are clearly a major problem, and depending on the demand variations and the underdeveloped infrastructure, operating performance is a critical issue in these countries and more so in operating performance does not lead to efficient management of production processes, design, and line balancing of production processes remains of paramount importance (Mohammed, 2023; Aliyu, 2024).

Productivity, Efficiency, and Quality Metrics

Productivity is the measurement of the amount of output produced against an input, relative to labor and machine and material efficiency. Efficiency also discusses the ideal utilization of the resources and avoiding wastage and down time but also quality measures conformance to specifications and customer expectations (Cua, McKone, & Schroeder, 2001; Vijay & Prabha, 2021). Lean manufacturing practices, Total Quality Management (TQM) and continuous improvement initiatives have proven effective to improve these metrics through workflow process streamlining and improved defect prevention and workforce engagement (Krafcik, 1988; Kaplan & Cooper, 1998).

Cost Reduction, Lead Time and Customer Satisfaction

Operational performance is strongly related to cost reduction and increased lead time. Through effective production processes, streamlined design layouts, and balanced production lines, the firms will be able to reduce overheads, reduce bottlenecks, as well as enhance faster productions (Vijay and Prabha, 2021; Slack, Chambers and Johnston, 2010). The satisfaction of the customers is increased when the products are delivered on time, with the appropriate quality and at affordable prices. Studies indicate that companies that have employed the integrated practice of line balancing, lean approaches, and process standardization have expressed higher levels of efficiency in their operations as well as increased sensitivity to variations in the market (Krafcik, 1988; Prajoko and Olhager, 2012).

Role of Integrated Production Strategies in Achieving Performance Targets

Combination of process optimization, innovative design and line balancing of integrated production strategies are most important in order to achieve performance targets. The joint effort of the organization of production processes and the design improvement, as well as the distribution of labor, balance are the guaranties of the uniformity of the processes, minimization of the variability of operations and increased productivity (Vijay and Prabha, 2021; Mohammed, 2023). Texts Major innovative manufacturers, such as Toyota and Siemens, all over the world have shown that the source of competitive advantage is such integration as superior performance in their operations (Krafcik, 1988; Kaplan and Cooper, 1998). These integrated strategies could be used to alleviate the inefficiencies in the operations which could lead to improved use of resources and place firms in the Nigerian context to address the rising demand across the domestic and international markets (Aliyu, 2024; Mohammed, 2023).

2.2 Theoretical Framework

Lean Production Theory

The Lean production theory is based on the rules of post-wastefulness, value and process constant improvement (Krafcik, 1988; Vijay & Prabha, 2021). The root of the idea is optimize workflows, eliminate non-value added activities, and make the overall manufacturing system efficient.

Lean production focuses on tools and techniques such as Just-in-Time (JIT) production, standardized work, total productive maintenance (TPM), and continuous improvement (Kaizen) to help improve operational performance (Cua, McKone, & Schroeder, 2001; Slack, Chambers, & Johnston, 2010). Globally, companies that use lean principles have improved levels of productivity, shorter lead times and improved product quality; and in developing regions, such as West Africa, lean principles offer a systematic way to address inefficiencies and resource constraints (Mohammed 2023; Aliyu 2024).

Theory of Constraints (TOC)

The Theory of Constraints (TOC) is concerned with the identification and control of bottlenecks that constrain system throughput and total operational performance of a system (Goldratt & Cox, 1984; Prajogo & Olhager, 2012). By systematically analyzing the production processes and assigning resources to limit points, TOC ensures better workflows, cycle times and delivery performance. Line balancing, optimized production design have a high correlation with TOC because they help in balancing workloads, avoid overloading, and ensure that the pace for production is maintained (Vijay & Prabha, 2021; Krafcik, 1988). In Nigeria and other developing countries, the TOC offers a useful tool for meeting the recurring production stoppages due to questionable limitations related to equipment, human forces and infrastructural limitations (Mohammed, 2023; Aliyu, 2024).

Rationale for Theory Selection

Lean Production and TOC were chosen to be the theories that will guide this study because they cover the fundamental aspects of the performance of operations in manufacturing systems comprehensively. Lean Production offers a holistic way for process improvement and waste reduction, focusing on efficiency, quality and productivity. TOC is complementary to this in the sense that it focuses on constraint management, which ensures that the production flows are optimized and that the bottlenecks do not compromise the performance (Cua, McKone, & Schroeder, 2001; Prajogo & Olhager, 2012). Together, these theories form a solid framework to process the role of production processes, design, and balancing of lines to operational performance in varied organization and regional situations ranging from global manufacturing giants down to Nigeria and West African firms (Mohammed, 2023; Vijay & Prabha, 2021).

2.3 Linkages between Theories, IVs, and DV

Production Process Improvements and Operational Efficiency

Production process improvement as guided by the Lean Production Theory affects more the performance of operations directly by identifying and removing wastage, optimizing the flow process, and improving the utilization of resources (Krafcik, 1988; Vijay & Prabha, 2021). Techniques such as Just-in-Time production, continuous improvement (Kaizen), and total productive maintenance (TPM) are available to help firms improve productivity, lower cycle time, and produce higher quality products. Globally, companies that adopt lean production strategies are known to have made huge strides in effectiveness and customer satisfaction, and in Africa and Nigeria, lean production strategies are playing a major role in dealing with the issue of resource limitations coupled with ineffectiveness and process variability (Mohammed, 2023; Aliyu, 2024).

Production Design and Waste Minimization

Effective production design based on the Theory of Constraints (TOC) relies on ensuring the physical layout, machine allocation and workflow structures dictate efficient production (Prajogo and Olhager, 2012; Krafcik, 1988). Design decisions that affect the material flow, reduce bottlenecks and improve the system throughput. By leveraging design and process improvement efforts, companies will be able to anticipate constraint and optimize the use of resources, leading to better performance operation (Vijay and Prabha, 2021; Mohammed, 2023).

Line Balancing and Workflow Optimization

Line balancing is concerned with balancing the load across the production operations with the goal of achieving a balance with regard to the production speed (takt time) while also avoiding idle time or bottlenecks (Vijay & Prabha, 2021; Cua, McKone, & Schroeder, 2001). Balanced lines help reduce delays, increase productivity and quality of outputs. In practical implementations, organizations that are successful in employing line balancing techniques report on measurable cycle time and cost efficiency improvements, as well as customer satisfaction (Slack, Chambers, & Johnston, 2010; Prajogo & Olhager, 2012).

Integrated Theoretical Linkage Model

The combination of Lean Production Theory and TOC provides a good theoretical background for relating the independent variables which are production processes (IV1), production design (IV2), line balancing (IV3) and the dependent variables which are operational performance (DV). Production processes supply the basis for efficiency improvements, production design assures efficient allocation of resources, bottleneck, while line balancing guarantees smooth flow of production and waste reduction. Together, these factors form a synergistic effect for improved productivity, quality, cost-efficiency, and improved operational performance in manufacturing systems worldwide, and regionally in Africa, and in Nigeria in particular (Mohammed, 2023; Vijay & Prabha, 2021; Prajogo & Olhager, 2012).

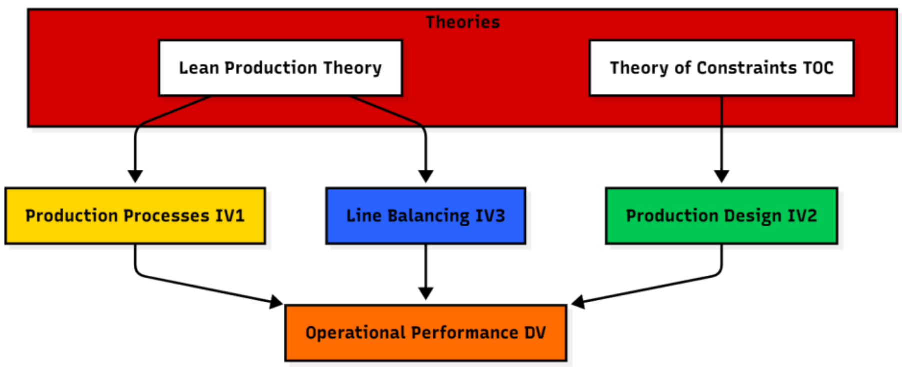

Figure 2.1: Integrated Theoretical Linkage Model of Production Processes, Design, and Line Balancing on Operational Performance

Source: Adapted from Mohammed (2023); Vijay & Prabha (2021); Prajogo & Olhager (2012).

The theoretical relation between production processes (IV1), production design (IV2), and line balancing (IV3) as the important driving force for operational performance (DV) is illustrated in the diagram. Lean Production Theory underpins production processes and line balancing with the reduction of waste, optimizing workflow, and gaining efficiency. The i.e Theory of Constraints, production design, identifying and dealing with bottlenecks to ensure smooth allocation of resources and cost-effective operations. Collectively, these independent variables operate in a synergistic relationship with each other, in order to promote a high-produced level in terms of productivity, quality, cost efficiency and overall operational performance in manufacturing/whole systems. This model underscores the fact that improvements in any one of these three dimensions, i.e. process efficiency, design optimization and balanced workflows, contribute directly to achieving better operational outcomes, not only at the global level but also in the African and Nigerian manufacturing situation (Mohammed, 2023; Vijay & Prabha, 2021; Prajogo & Olhager, 2012).

2.4 Empirical Review

Empirical studies have repeatedly shown the high importance of production processes in the improvement of manufacturing performance. For instance, Vijay and Prabha (2021) investigated the work standardization and line balancing in a windmill gearbox manufacturing cell and showed that the adoption of the standard operating procedure (SOP) and continuous improvement Kaizen techniques resulted in substantial reductions in cycle time as well as improvements in the productivity. Similarly, Kaplan and Cooper (1998) emphasised on activity based costing and integrated cost management system where firms can identify process inefficiencies and optimize utilisation of resource and improve overall operational performance. Globally, various companies that have implemented lean manufacturing principles have claimed to achieve greater efficiency, less wastage and faster throughput, thus establishing that well-organized and optimized production processes directly affect performance results.

In addition, the production design and line balancing have proven to be important factors relating to the operational efficiency. Effective production design such as the layout of the workflow, machine allocation and ergonomics involves manufacturing resources are being used to their maximum advantage minimizing bottlenecks and downtime (Drucker, 1990; Krafcik, 1988). Line balancing that is distributing workloads evenly across operations, production should be aligned with the idea of takt time that is minimizing idle time and enhancing throughput (Vijay & Prabha, 2021; Prajogo & Olhager, 2012). Case studies from both developed and developing economies suggest that companies that follow integrated strategies of production design and line balancing have consistently improved quality output, reduced production costs and lead time, proving the relevance of these operational techniques in the field.

Evidence from the developing countries adds to the support for the global applicability of these practices. In Nigeria and West Africa more broadly, research by Mohammed (2023) and others has found that manufacturing companies are five times challenged with limited technological infrastructure and workforce skill deficit mainly limited to the factor of workforce technical skills but firms using standard process, optimized design of production and production line balancing in their operations are measureably improved in their operational performance. Comparative studies in Asia, Africa, and Europe seem to indicate that although contextual factors such as local labor practices and resource availability may impact implementation processes, the basic principles of effective production processes, strategic designs and line balancing are crucial to attaining sustainable operational outcomes (Kaplan, 1983; Krafcik, 1988; Prajogo & Olhager, 2012). These results highlight the necessity to use integrated manufacturing strategies to improve efficiency, quality and general competitiveness in various regional contexts.

2.5 Research Gap

Conceptually, while there are significant number of researches investigating production processes independently of production design, the line balancing or vice versa, there are a limited number of studies investigating all three variables integrated together to assess their common impact on operational performance. Most journals available are centered on one aspect of the improvement of manufacturing, such as lean methods or line balancing on their own (Vijay & Prabha, 2021; Cua, McKone, & Schroeder, 2001). This piecemeal approach is limiting the understanding of the synergy that these variables may have when implemented as a whole, especially in terms of improving productivity, decreasing waste and improving overall operational efficiency. A comprehensive conceptual framework of the link between production process, design, and line balancing and its implications for operation performance is therefore required to bridge this gap.

Contextually, the absence of empirical studies in terms of industries or regions is very noticeable, especially on developing economies like Nigeria and others in Africa. While literature on global studies offers information on various types of manufacturing systems in Europe, North America and Asia (Krafcik, 1988; Prajogo and Olhager, 2012), the peculiar challenges of operational challenges in African manufacturing systems with infrastructural constraints, workforce skills gap, weak technological adoption are often underexplored (Mohammed, 2023; Vijay and Prabha, 2021). This makes a contextual gap exist in that some of the findings in the developed countries could not totally define to local set up, this makes the need for region specific that is to tackle operational realities in Africa and West Africa, Nigeria included.

Methodologically, few of the few studies use integrated measures of operational performance that include productivity, quality, cost efficiency, and lead time all at the same time. Many investigations concentrate on isolated metrics, which limit the possibility to catch the holistic impact of production strategies on manufacturing resulting (Kaplan & Cooper, 1998; Prajogo & Olhager, 2012). There is a need for studies that has multi-dimensional performance indicators, a combination of quantitative and qualitative indicators, to determine the effectiveness of production processes, designing improvements, and line balancing altogether. Addressing this methodological gap will help the researchers and practitioners to form more rigorous and applicable insights to optimize the working performance in diverse manufacturing environments.

2.6 Conceptual Framework of the Study

The conceptual framework of this study shows the integrated relationship of production processes (IV1), production design (IV2), and line balancing (IV3) as the independent variables and operational performance (DV) as the dependent variable. Production processes are expected to improve efficiency and minimize wastage, production design is aimed at optimizing the workflow, resource allocation and cost-effectiveness while line balancing is responsible for smooth flow of operations and idle time. Collectively, these factors have been hypothesized to positively influence operational performance in terms of improving productivity, quality and lead-time and customer satisfaction across manufacturing systems across the globe, Africa and Nigeria in particular (Mohammed, 2023; Vijay and Prabha, 2021; Prajogo and Olhager, 2012).

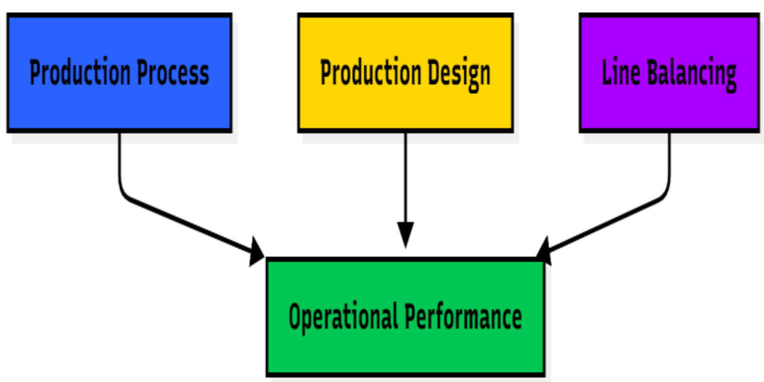

Figure 2.2: Conceptual Framework Linking Production Factors to Operational Performance

Source: Mohammed (2023); Vijay & Prabha (2021); Prajogo & Olhager (2012)

The diagram is a visual representation of the hypothesized relationships between the variables of the study indicating that production process improvements, optimized production design and effective line balancing are all key drivers of operational performance. Each independent variable makes its own unique contribution to the business: production processes can ensure that operations run smoothly, and production design can make sure that resources are used well and costs are kept under control, while line balancing can help minimise bottlenecks and idle times. Together, they produce a synergistic effect expected to improve productivity, product quality, reduction of lead time and general manufacturing efficiency. This framework has offered structured basis for empirical testing and provides a good guide in managers to integrate the production strategies for good operational results.

3.0 Research Methodology

This work has adopted conceptual research approach, which is based on the theoretical analysis and literature analysis to discuss the impact of production processes, production design and line balancing to the operational performance. As conceptual study, that is not related to primary data collection: rather, scholarship is synthesized to create the integrated understanding of the relations among the variables (Mohammed, 2023; Vijay & Prabha, 2021). Theoretical underpinnings derived from Lean Production Theory and Theory of Constraints are used to guide the analysis and provide the framework for a link between the independent variables and operational outcomes.

The strategy for the literature selection for this study included a systematic literature review of peer-reviewed journals, conference proceedings, and case studies pertinent to the areas of manufacturing performance, production design, line balancing, and operational efficiency. Databases such as Scopus, Web of Science and Google Scholar were utilized in identifying and identifying quality studies with special focus on global, African, West African, and Nigerian context with a view to obtain a comprehensive perspective (Prajogo & Olhager, 2012; Krafcik, 1988; Cua, McKone, & Schroeder, 2001). The criteria used to select the concepts included must have been relevant, as well as methodologically sound, and consider recent issues, as the overriding requirement was that the conceptual model should reflect contemporary trends and practices.

The conceptual analysis method will be synthesizing the previous empirical and theoretical evidence to form the proposed framework to the production processes, production design and line balancing to operational performance. In this manner, one can determine the patterns, gaps, and patterns within the literature and based on this, establish cohesion as far as a model of the manufacturing process improvement is concerned. The research, through extracting diverse insights into the field of the global and regional research, may be viewed as an organized theoretical base that can serve as inputs in subsequent empirical research and actualization of the research in manufacturing environments.

4.0 Findings of the Study

1. This research revealed that through the normalization of production processes, indicators of operational performance, including efficiency, quality and productivity, increase significantly. By introducing structured and repeatable processes, firms have the potential to reduce the variability and minimize the error levels, while also improving the overall throughput (Vijay & Prabha, 2021; Kaplan & Cooper, 1998).

2. Design improvements of the production processes were recognized to be critical in enhancing the working process with reduction in time cycle and maximization of the resources. Efficient layout, work ergonomics, process advancement efforts, and incorporation leads to organizational operations being facilitated faster and resources being distributed more effectively Drucker (1990) and Prajoko and Olhager (2012).

3. It was found that line balancing had a partly quantifiable impact on the performance at the operational level, such as throughput, the use of labor and minimization of bottlenecks. It is possible to achieve balanced workstations, which means that idle time is requested and more predictable production schedules (Krafcik, 1988; Vijay and Prabha, 2021).

4. The net effect of standardization of the production process, the enhanced design and the efficient line balancing are as follows and serve the sustainable operation performance. Combined, these would be played out in terms of enhanced productiveness, cost-effectiveness, quality and response effectiveness in the production processes (Cua, McKone, and Schroeder, 2001; Prajoko and Olhager, 2012).

5. The study is designed to provide useful lessons to the manufacturing managers to demonstrate how incorporation of production strategy could result in improved manufacturing results not only in the local dynamics of

countries such as Nigeria and West Africa, but also in the overall production environment. Managers are perfectly ready to target the interventions that yield quantifiable returns in terms of performance (Mohammed, 2023; Vijay and Prabha, 2021).

5.0 Study Recommendations

1. The production processes should be standardized by the manufacturing organizations to assure efficiency, quality, and production in general. The main problem in maintaining performance gains is by documenting the processes clearly and ensuring the continuous improvement mechanism (Kaplan and Cooper, 1998; Vijay and Prabha, 2021).

2. The production design is to be streamlined to achieve better workflow and cycle time and ensure that resources are used efficiently. This is comprised of ergonomic designs, use of digital technologies, and the integration of design enhancement with operational goals (Drucker, 1990; Prajoko and Olhager, 2012).

3. They should consider a set of line balancing strategies that would balance the workloads equally and reduce cases of idle time and bottlenecks. To maintain the performance at its optimum level, continuous focus on the takt time and sequence of production control can be advised (Krafcik, 1988 and Vijay and Prabha, 2021).

4. Process standardization, design improvement and line balancing initiatives should be considered by the manufacturing managers in order to achieve sustainable operational performance. The holistic approach guarantees the synergistic rewards, including the increased throughput, labor utilization, as well as the improved quality (Cua, McKone, and Schroeder, 2001, Prajogo and Olhager, 2012).

Further scholars and the policy makers need to work towards the formulation of frameworks and guidelines to understand how one can measure and enhance the performance of operation in the manufacturing companies especially in the developing economies like Nigeria and West Africa. Emphasis should be laid on context-specific strategies and interventions to ease industry-wide adoption (Mohammed, 2023; Vijay & Prabha, 2021).

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