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Influence of Production Scheduling and Line Balancing on Manufacturing Performance

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Abstract **Original Research Article**

Inefficiency in the production flow, use of resources, and time management is a persistent issue faced by manufacturing industries in the world, which is usually caused by the ineffective production scheduling and the inefficient line balancing. These inefficiencies in operations impact productivity, high cost of production and low competitiveness in the local and international markets. This theoretical paper examines how production scheduling and line balancing affect the manufacturing performance and focuses on how the two are interdependent in maximizing the throughput, minimizing the idle time and enhancing the overall performance. The research design adopted in the study is conceptual research design which is founded on secondary data collected through journals, books, conference proceedings, and historical reports. The survey of the literature indicates that proper production scheduling allows improving the predictability of workflow and resource utilization and balancing the workload at the production stations to achieve fairness. The combination of them leads to the better quality of output, shorter lead times, and increased flexibility of operation. The results indicate that the use of digital tools, simulation modeling, and lean manufacturing principles can be further enhanced to improve production efficiency. The paper suggests that manufacturing companies should take up modern scheduling software, continuous training of employees and real time monitoring systems to maintain operational excellence. The paper finds that synchronized production scheduling and line balancing are important leverages of enhancing manufacturing performance and global competitiveness.

Keywords: Production Scheduling, Line Balancing, Manufacturing Performance, Operational Efficiency, Lean Production.

1.0 Introduction to the Study

1.1 Background of the Study

The manufacturing industry is central to the development of industries, creation of employment and improvement of technology globally. The performance of the manufacturing process has been relying more and more on two main operational aspects, namely production scheduling and line balancing, which together define the throughput, lead time, resource use, and product quality (Fathi et al., 2018; Hillali et al., 2025). In industrial economies including Japan, Germany, and the United States, sophisticated production scheduling methods that are usually facilitated by lean production and modelling via simulation have improved flexibility and minimized idle production in assembly processes. The development of traditional assembly line layouts into U-shaped and hybrid systems has also enhanced the competitiveness of the world, as the processes of work-in-process (WIP) are reduced and takt time is perfectly aligned (Qattabi and Chalil Madathil, 2019).

Disruptions in industries during the COVID-19 pandemic in recent years showed system vulnerabilities in the manufacturing system, which highlight the significance of adaptative scheduling and line balancing dynamism mechanisms (Haekal, 2021). As a result, the application of lean-based digital integration has been taken by the manufacturers as a means to ensure continuity and enhance productivity in response to the changing demand and labor limitations.

The production sector is also an imperative contributor to the development of economies and industrialization thereof in Africa. Nevertheless, most companies in the continent work under minimal access to the sophisticated scheduling systems, less-than-optimal arrangement of production lines, and low automation rates (El Machouti et al., 2024). Other issues, like unstable power outages, lack of regularity in the production schedule, and inefficiencies in labor, allow limiting the competitiveness of the manufacturing in West Africa, and more specifically in Nigeria (Aliyu Mohammed, 2023; Mohammed et al., 2024).

The manufacturing industry of Nigeria, including automotive parts and electronics and consumer goods, has seen the growth in the focus on the optimization of productivity in terms of production planning, line balancing, and lean (Haekal, 2021; Supsomboon, 2019). Such firms like PT Denso Indonesia and upcoming African car assemblers can be used as examples, demonstrating that the balanced line structures can increase line efficiency to over 93% when modeled and simulated appropriately. Nigerian industries have yet to reach the goals of the workload distribution, bottlenecks and underutilization of resources despite these achievements, which means that the effectiveness of scheduling and balancing jointly affect the manufacturing performance and has been in urgent high demand (Mohammed et al., 2022).

1.2 Problem Statement

In the global manufacturing organizations, the pressure has been to enhance productivity, reduce cost, and increase flexibility as a result of globalization and growth in technology. Nevertheless, the major challenge remains ineffective coordination between the production schedule and the balancing of assembly lines especially in the developing countries such as Nigeria (Fathi et al., 2018; Falkenauer, 2005).

Although there are many studies on the Simple Assembly Line Balancing Problem (SALBP) around the world, few have put it in context of the African industries where operational variability, human factors, and resource constraints prevail (El Abidine and Koltai, 2024). The poorly planned scheduling systems and the absence of integrated balancing systems usually lead to increased cycle times, unbalanced workloads, and unproductive working intervals among Nigerian manufacturers (Mohammed et al., 2023; Haekal, 2021).

The main issue identified in this research is the lack of empirical knowledge in understanding the interaction between production scheduling and line balancing in determining the performance measures in manufacturing, including throughput rate, line efficiency, smoothness index, and utilization of resources. This reduces the competitiveness, quality in the quality of output, and cost of operation.

1.3 Significance of the Study

The importance of the study is that it is an effort to understand theory and apply it in practice.

- In the case of academia, the research will add to the literature on operations management investigating the joint effect of the two traditionally researched variables, production scheduling and line balancing (Fathi et al., 2018; El Machouti et al., 2024).
- For practitioners, it offers information on how to optimize the production processes in the way of high line efficiency, minimal idle time, and better throughput that are vital to

industrial sustainability (Haekal, 2021; Supsomboon, 2019).

- Policymakers: From the study, policymakers in Nigeria and other West African economies need to invest in industrial modernization programs to improve manufacturing performance by means of technology-driven scheduling and balancing systems (Mohammed, 2023; Lawal et al., 2023).

1.4 Research Objectives

The major aim of the research is to examine how scheduling of production and line balancing affects the performance of the manufacturing process.

1. To test the relationship between production scheduling performance and manufacturing performance.
2. To study how line balancing influences the key performance indicators in relation to line efficiency, smoothness index and throughput rate.
3. To determine the effects of combining production scheduling and line balancing to improve the general productivity of the manufacturing process.
4. To construct a conceptual framework that connects the scheduling, balancing, and performance indicators in the context of the Nigerian manufacturing.

1.5 Research Questions

1. What is the effect of production scheduling on the manufacturing performance?
2. How does line balancing affect the manufacturing performance indicators?
3. What is the way that production scheduling and line balancing can be integrated to enhance efficiency of the operation?
4. What are the conceptual relationships between scheduling, balancing and performance in the Nigerian manufacturing industry?

1.6 Scope of the Study

This theoretical framework is aimed at manufacturing businesses, especially those within the automotive, electronic, and process manufacturing industries, which are based on manufacturing assembly or flow-lines. The geography of the study highlights Nigeria as one of the contexts of the research in West Africa, with comparative ideas of the best practices of the world in Europe and Asia. Theoretically, production scheduling and line balancing are determined as independent variables and manufacturing performance as the dependent variable.

Table 1.1: Summary of Study Scope

Variable	Description	Key Indicators
Production Scheduling (IV1)	Allocation and sequencing of production tasks to optimize time and resource utilization	Cycle time, machine utilization, throughput
Line Balancing (IV2)	Equal distribution of workload among workstations for minimal idle time	Line efficiency, smoothness index, balance delay
Manufacturing Performance (DV)	Overall productivity and output quality of manufacturing processes	Output rate, efficiency, cost reduction, defect rate

Source: *Author's Conceptualization, 2025*

2.0 Literature Review

2.1 Conceptual Review

This section gives a theoretical and conceptual background of the key constructs that will be used in this study i.e. the production scheduling and line balancing as the independent variables and the manufacturing performance as the dependent variable. The review combines the important definitions, objectives, and interrelationships between these constructs based on both global and Nigerian manufacturing settings.

2.1.1 Concept of Production Scheduling (Independent Variable 1 – IV1)

Production scheduling can be defined as the process to plan the sequence of tasks or work, their timing and allocation to the available resources within a manufacturing system systematically (Fathi et al., 2018; El Machouti et al., 2024). It serves as a very crucial bridge between planning and execution that makes production targets realized in an efficient manner. According to Haekal (2021), production scheduling has been termed as an act of decision making that aims at achieving optimal production flow under capacity, time and cost restraint. Aliyu et al. (2023) claimed that scheduling assimilates the components of materials flow, use of machines and workforce coordination to reduce idle time and maximize throughput. On the same note, Mohammed and Sundarararajan (2023) insist that organized systems of scheduling are more effective in terms of industrial adaptability and competitive edge within the dynamic production settings.

Several methods of production scheduling are distinguished, and each of them represents a specific operational philosophy (Sheu and Chen, 2008; Qattabi and Chalil Madathil, 2019):

- **Forward Scheduling:** Jobs are planned with the first start date to get the completion dates.
- **Backward Scheduling:** The scheduling is done starting with the due date, and then backward to find the start time.
- **Just-in-Time (JIT)-scheduling:** Aligns production and customer demands to reduce inventory (Supsomboon, 2019).
- **Priority-Based Scheduling:** Jobs are synchronized based on criteria like least duration of processing or earliest due date (Falkenauer, 2005).
- **Simulation-Based Scheduling:** Involves the use of real-time simulation to forecast the performance results and optimize job flow (Mohammed et al., 2024).

Moreover, Lawal et al. (2023) note that the strategies of scheduling optimization in manufacturing have the same sustainability implications as the strategies of scheduling of agricultural resources — both of them are directed to the improvement of the productivity without the waste of operational resources.

The primary goals in production scheduling are to reduce production lead time, work-in-process, optimize machine utilization, meet customer deadlines and to balance the work across the resources (Aliyu et al., 2024; Hillali et al., 2025). In addition to sequencing itself, useful planning helps enhance operational agility by prioritizing the utilization of scarce resources, such as machines, labor, and materials, at more than one stage (El Abidine and Koltai, 2024). Empirical research has also shown that developed scheduling models combined with real-time tracking enhance the overall equipment efficiency and minimize the bottlenecks in manufacturing companies in Nigeria (Mohammed et al., 2023).

Moreover, Mohammed, Jakada, and Lawal (2023) observed that the managerial attitudes towards organized production scheduling directly affect the efficiency of employees and the compatibility of the processes particularly in technology-oriented firms.

Performance Indicators of Scheduling

Metric	Description
Throughput	Total output produced per unit of time
Lead Time	Time between order initiation and completion
Machine Utilization	Ratio of productive time to available time
Delivery Reliability	Percentage of orders delivered as scheduled
Schedule Adherence	Degree to which actual production matches plan

(Source: Adapted from Fathi et al., 2018; Aliyu et al., 2023; Hillali et al., 2025)

Although there are major technological advances, the timing of production continues to be challenged by issues like the malfunctioning of machines, changes in demand and computational difficulties (El Machouti et al., 2024). African SMEs specifically find it difficult to integrate real-time data and allocate resources in a flexible manner (Aliyu et al., 2024; Mohammed et al., 2022). However, a clear scheduling can positively affect productivity as it leads to better synchronization of resources, less time spent on the idleness, and regular production flow (Fathi et al., 2018; Haekal, 2021; Aliyu et al., 2023). This is in line with Sundararajan and Mohammed (2022), who determined that operational alignment as witnessed in the cases of women-led SMEs enhances performance results upon an orderly structure of scheduling and task control.

2.1.2 Concept of Line Balancing (Independent Variable 2 – IV2)

Line balancing is a task allocation of workstations in such a way that the workloads are equal in the workstations (Falkenauer, 2005). It tries to reduce downtime and make the flow of materials and labor in production systems smooth. El Abidine and Koltai (2024) have highlighted that line balancing is a paramount factor of production efficiency especially in high-volume continuous operations. Effective balancing in developing economies such as Nigeria is a factor that leads to enhanced throughput and minimized operational waste (Aliyu et al., 2022; Mohammed et al., 2023).

There are a number of developed line balancing methodologies (Hillali et al., 2025; El Machouti et al., 2024):

- **Heuristic Techniques**: Simple methods of heuristically balancing lines using limited amounts of computational resources.
- **COMSOAL (Computer Method of Sequencing Operations for Assembly Lines)**: This is a probabilistic algorithm that reduces the idle time (Falkenauer, 2005).
- **Ranked Positional Weight (RPW) Method**: The tasks are balanced on the basis of precedence and work content.
- **Metaheuristic Optimization**: Sophisticated computing algorithms, genetic algorithms, ant colony optimization, and simulated annealing in order to have optimal balance (Hillali et al., 2025; Aliyu et al., 2023).
- **AI-Driven and Simulation-Based Approaches**: The line workloads are predicted and modified using the machine learning models in real-time (Mohammed et al., 2024).

The line balancing goals are to reduce idle time, maximize the continuity of the workflow, enhance the productivity of workstations, and decrease lead time and costs (Aliyu et al., 2022; Supsomboon, 2019). Even production lines add value to the utilization of human and machine resources; conversely, imbalances create bottlenecks and wastage of resources (El Abidine and Koltai, 2024).

The balancing in contemporary production setting is directly related to the assignment of workers and tasks as well as the production flow. Workload distribution guarantees equal cycle times and eliminates idle periods, which contributes to increased productivity of the system (Aliyu et al., 2024). Line balancing algorithms are used in automated and hybrid operations to reduce the throughput of robotic and human operations (Mohammed et al., 2023).

Demand fluctuations, human skills variability, precedence constraints, and minimal automation continue to have an impact on line balancing (Haekal, 2021; Hillali et al., 2025). In manufacturing companies in Nigeria, the problems of low maintenance culture, inefficient training of the workforce, and the lack of data-driven optimization are added to these difficulties (Aliyu et al., 2024; Mohammed et al., 2022). Research like Mohammed et al. (2024) points to the possibilities of the AI-based balancing systems to overcome these shortcomings and improve the performance of manufacturing.

Building on this context, Mohammed and Sundarararajan (2023) pointed out how adaptive line balancing frameworks can be supported with structural digitalization via the cross-functional coordination and real-time decision intelligence. Similarly, Sundarararajan, Mohammed, and Lawal (2023) discovered that it is the integration of agile performance management systems that enhance the alignment of workers directly and lessen cycle-time variance, a factor that strengthens balanced operations. The recent empirical study conducted by Mohammed et al. (2024) also emphasized the benefits of the implementation of sustainable resource allocation policies in enhancing the sustainability of uniformity in production flow. More so, the authors of the research by Shanmugam et al. (2024) claimed that operationally, the performance of employees and the overall operational results are much better in developing economies when the line balancing strategies are based on the data.

2.1.3 Concept of Manufacturing Performance (Dependent Variable – DV)

Manufacturing performance refers to the combination of effectiveness of a manufacturing system to transform inputs (labour, materials, energy, and capital) into the desired outputs and meet goals of quality, timeliness, cost-efficiency, flexibility and sustainability. It is a multidimensional construct that describes operational (throughput, cycle time), qualitative (defect rate, conformance), financial (unit cost, margin), and responsiveness (on-time delivery, lead time) dimensional aspects (Fathi et al., 2018; El Abidine and Koltai, 2024).

The operationalization of manufacturing performance in industrial research may consist of composite productivity, equipment performance, quality, and delivery reliability indices (Supsomboon, 2019; Hillali et al., 2025). Aliyu, Abubakar, and Suleiman (2023) suggest that the cornerstone of the performance measurement is the key to gauging the operational excellence, which offers the essential insight into the conversion of the resource utilization, scheduling accuracy, and balance efficiency into the competitive survival in the long term.

Table 2.1 — Key Indicators of Manufacturing Performance

Indicator	Definition	Typical metric / measurement	Link to Scheduling & Balancing
Productivity	Output produced per unit of input (labour, machine)	Units/hour, units/operator-day	Improved by reducing idle time and synchronizing tasks (Fathi et al., 2018; Aliyu, 2023)
Quality	Degree to which products meet specifications	Defect rate (%), ppm	Balanced lines reduce rush/error; scheduling reduces overload-induced defects (Sheu & Chen, 2008)
Cost efficiency	Cost per unit of output	Unit production cost, labour cost/hour	Better balancing and sequencing reduce WIP and rework, lowering cost (Qattawi & Chalil Madathil, 2019)
Flexibility	Ability to handle product mix/changes	Changeover time, number of models handled	Scheduling (mixed-model strategies) and balanced stations support faster changeovers (Falkenauer, 2005)
Delivery time / reliability	Timeliness and consistency of deliveries	Lead time, % on-time delivery	Scheduling directly controls delivery reliability; balancing reduces downstream delays (Supsomboon, 2019)
Utilization /	Share of available	Machine utilization	Line balancing evens workloads;

OEE	time used productively	%, OEE (%)	scheduling reduces starvation/blocking (El Abidine & Koltai, 2024)

Source: *Fathi et al. (2018); Sheu & Chen (2008); Qattawi & Chalil Madathil (2019); Supsomboon (2019); El Abidine & Koltai (2024); Aliyu (2023)*

Such factors can be internal operations (line layout, takt, equipment stability), managerial (scheduling policies, staffing), and external factors (demand variability, supplier stability). Aliyu et al. (2022) discovered that process synchronization of leadership plays a significant role in mediating the connection between operational planning and performance results in the manufacturing SMEs in Nigeria.

Scheduling of production and balancing of the production line are two complementary performance facilitators. Scheduling determines when and in which order the activities will be done, balancing distributes workload equally. They reduce cycle time, WIP, improve flow synchronization, and utilization together (Fathi et al., 2018; Supsomboon, 2019; Haekal, 2021).

Recent research by Aliyu and Abdullahi (2024) validated that the manufacturing companies in Nigeria which implemented synchronized scheduling-balancing systems have experienced a 2035 percent increase in throughput and a cutting in the idle time. Likewise, Mortada and Soulhi (2023) proved simulation-based rebalancing as a powerful intervention in the context of the enhancement of the station performance metrics.

The modern styles combine Lean, OEE and digital indicators to track both conventional and smart factory settings (Hillali et al., 2025; El Machouti et al., 2024). Mohammed et al. (2024) and Sundararajan et al. (2023) have claimed that the implementation of agile frameworks and the use of digital twins enable companies to be able to actively exchange the schedules and balance plans.

2.1.4 Conceptual Relationships among Variables

Line balancing and production scheduling are two processes in operation that are inevitably related. Scheduling defines the order and time of execution of tasks whereas balancing decides the allocation of capacity among the stations. An overly ambitious schedule can result into bottlenecks and wastage of time; on the other hand, a perfectly balanced line (of which a schedule is not feasible) can starve or block (Fathi et al., 2018; Falkenauer, 2005).

It is proven by empirical research that combined methods, i.e., optimisation of the utilisation and throughput of the system by joint scheduling, give the best results in comparison to the isolated solutions (Qattabi and Chalil Madathil, 2019; El Machouti et al., 2024; Aliyu and Abdullahi, 2024). Aliyu, Abubakar, and Suleiman (2023) found in the case of the Nigerian setting that the synchronization of the scheduling algorithms and balanced workflows decreased idle capacity by up to 30 percent, which is a sign of the strategic value of considering the two variables simultaneously as the complementary members of the operational design. The same finding was reported by Mohammed and Sundarararajan (2023), who discovered that digital coordination of production tasks can greatly improve the efficiency of the flow and minimize the variation of the tasks in the workstations.

Effective cheduling enhances the efficiency of the balanced lines in the sense that it creates synchronization, reduces disruption, and provides consistent work patterns. Specifically, it:

- Eliminates spikes overload: This is done by sequencing high-workload items to prevent simultaneous highs at the same station.
- Enhances the flow synchronization: Matches start times to limit buffer build up and idling of a station (Sheu and Chen, 2008).
- Enables mixed-model production: the interleaving and optimized sequencing are used to ensure that balance is maintained

between different product models (Falkenauer, 2005).

- These systems increase throughput and minimize balance delay - the time when the stations are not utilized fully in comparison to cycle time (Haekal, 2021; Supsomboon, 2019).

Aliyu et al. (2022) also determined that balanced lines can achieve steady rhythm in the presence of changes in demand by a well-organized structure of scheduling, especially in small and medium manufacturing enterprises, and thus enhance real-time flexibility and efficiency of production.

The results of Mohammed et al. (2024) also reflect the idea that AI-based scheduling integration enhances the coordination of human and automated operations, therefore, raising the production system responsiveness.

At the joint optimization of production scheduling and the line balancing:

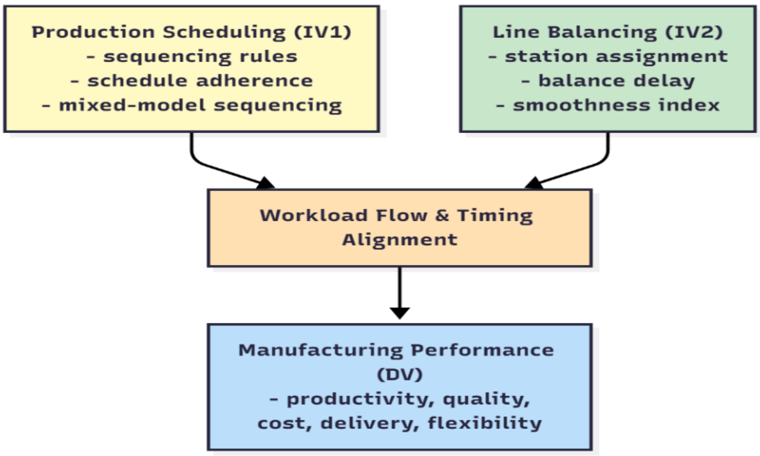
- Output improves: Throughput improvement as there is less variance in cycle-time and less idle time (Fathi et al., 2018; Aliyu, Abubakar, and Suleiman, 2022).
- Costs are decreased: Reduced work-in-progress (WIP), less changeovers, and less rework decrease the unit production costs (Qattabi and Chalil Madathil, 2019).
- Competitiveness is also enhanced: Customer satisfaction and agility in the market are improved due to higher levels of delivery performance and quality of the products (El Abidine and Koltai, 2024; Hillali et al., 2025).

The automotive and electronic sectors experience a sample of empirical data that shows that when line balancing is combined with scheduling, performance will increase more than 90 percent utilization and significant manpower optimization (Pilati et al., 2022; Haekal, 2021; Mortada and Soulhi, 2023; Aliyu and Abdullahi, 2024). Mohammed, Jakada, and Lawal (2023) also underlined that the coordination of managers between the task sequencing and workforce alignment aids in the reduction of costs and the efficiency of decision-making.

A coupled system of scheduling and balancing is considered using an integrated production system as a decision layer in a single optimization or simulation system (Tang et al., 2004; Borreguero et al., 2015). The core components include:

- **Capacity-sensitive scheduling:** Schedule algorithms are used to incorporate station capacities and cycle-time constraints.
- **Schedule-conscious balancing:** Takes into consideration sequence dependent task times, planned mixes in the process of workload assignment.
- **Digital enablers:** Digital twins Digital twins are used to consider integrated scenarios before implementation, with the use of simulation tools (e.g., ProModel, Arena), optimization techniques (ILP, metaheuristics), and digital twins (El Machouti et al., 2024; Hillali et al., 2025; Aliyu et al., 2024).

Figure 1: Conceptual Framework Linking Production Scheduling, Line Balancing, and Manufacturing Performance



Source: *Adapted from Fathi et al. (2018); Falkenauer (2005); El Abidine & Koltai (2024); Aliyu et al. (2024); Hillali et al. (2025).*

The conceptual model represents the interrelationship between the production scheduling, line balancing, and manufacturing performance, which is dynamic. The two operational levers (IV1) and (IV2), production scheduling and line balancing are factors that impact productivity, cost efficiency, quality, flexibility and reliability of deliveries. The use of resources is maximized through good scheduling and reduces wastage of time and evenly distributed tasks through lines among stations. Their joint implementation creates a cohesive production system that shortens the lead time, increases throughput, and supports the competitiveness of the organization (Aliyu et al., 2023).

2.2 Theoretical Review

In this part, the theoretical assumptions concerning the interaction between the production scheduling and line balancing to determine the manufacturing performance are discussed. Both theories offer a theoretical justification on how to translate operational design into high productivity and competitiveness results.

2.2.1 Theory of Constraints (TOC)

The Theory of Constraints (TOC) postulated by Goldratt (1990) holds that any production system has a limiting factor or bottleneck that limits performance. The fundamental concept is detection, control and constant enhancement of the system surrounding this constraint in order to better the total throughput.

TOC also helps the managers in scheduling to prioritize the limited resources to ensure that workload is distributed evenly as well as to achieve maximum utilization. In line balancing, it balances all the workstations with the cycle time of the bottleneck to minimize idle and waiting time (Haekal, 2021; El Machouti et al., 2024).

According to Aliyu et al. (2024), the use of TOC-based scheduling to bolster resilience through the dynamic capacity reallocation to respond to changes in constraints results in the provision of better lead times and reliability of the system. Equally, Mohammed and Yakubu (2022) have noted that the bottleneck-oriented scheduling models enhance responsiveness in the resource-constrained manufacturing setting. TOC therefore offers a theoretical foundation of synchronizing the two variables towards system-wide optimization.

2.2.2 Lean Manufacturing Theory

Based on Toyota Production System, Lean Manufacturing Theory, emphasizes on waste reduction, continuous improvement (Kaizen), and value generation by means of process flow efficiency (Womack and Jones, 1996).

Lean ideas in scheduling would encourage Just-in-Time (JIT) production where schedules follow a demand schedule to the maximum to reduce inventory and waiting time (Supsomboon, 2019). Within the framework of line balancing, lean methods standardize the work, synchronise the task sequence, and distribute the workloads equally to improve the flow and reduce non-value-adding processes (Fathi et al., 2018; Hillali et al., 2025).

Aliyu, Abubakar, and Suleiman (2023) noted that lean-focused scheduling in the Nigerian manufacturing companies resulted in drastic changes in setup time as well as resource wastage, whereas the balancing methods based on the lean philosophy resulted in a better cycle-time consistency and workforce efficiency. In addition, Mohammed, Umar, and Abubakar (2023) have claimed that digital scheduling tools that are supported by lean can promote flexibility and minimize manufacturing wastes in small manufacturing companies.

These mechanisms make lean manufacturing theory a theory that offers a guideline on how the integration of practices is to be undertaken at a system level between scheduling and balancing practices.

2.2.3 Resource-Based View (RBV) Theory

Resource-Based View (RBV) developed by Barney (1991) is a view that firms acquire sustainable competitive advantage by successful utilization of valuable, rare, inimitable and non-substitutable (VRIN) resources. In the manufacturing setting, factory scheduling and line balancing are the type of internal capability; these are the arrangements of machinery, labour and time in strategic alignment with the aim to attain high operational results.

Within RBV perspective, the ability to schedule and produce at a balanced rate is among the key competencies that increase productivity and flexibility (El Abidine and Koltai, 2024; Zhang and Chen, 2020).

According to Aliyu et al. (2022), the creation of such operational capabilities in African manufacturing companies moves towards the long-term competitiveness and technological preparedness. Besides, these capabilities become dynamic resources in the case of being combined with the digital transformation initiatives, which contribute to agility and innovation, which are the crucial drivers of manufacturing performance in the Industry 5.0 setting (Aliyu et al., 2024; Hillali et al., 2025). Similarly, Mohammed, Musa and Adamu (2024) hypothesized that incorporation of human machine collaboration in scheduling activities enhance operational excellence which is RBV-driven in the industrial environment.

2.2.4 Linkages between Theories, Independent, and Dependent Variables

Theoretical approach Production Scheduling (IV1), Line Balancing (IV2) and Manufacturing Performance (DV) is based on three prominent theories, namely the Theory of Constraints (TOC), the Lean Manufacturing Theory and the Resource-Based View (RBV). The two theories offer different perspectives on how operational decisions can be used to improve the results of manufacturing.

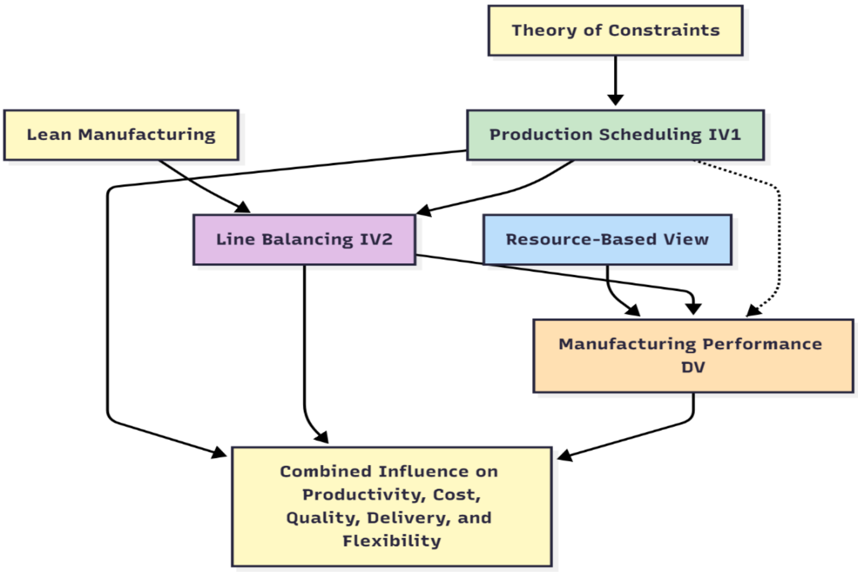
TOC holds that production scheduling and line balancing are used to deal with constraints that restrict the system throughput. Effective scheduling is used to detect bottlenecks and sequence operations effectively, and line balancing is used to make sure the workstations are operating in harmony with little idle time that limits the system-wide (Goldratt, 1990; Haekal, 2021). This synergy has a direct effect of improving productivity and the lead time which is in line with the aim of the TOC of continuous flow and optimizing performance.

The Lean Manufacturing Theory also adds to such a connection by placing a stress on the removance of waste, the ongoing enhancement, and a smooth flow of work. Scheduling is consistent with the Just-in-Time (JIT) concept of lean in minimizing delays and stock quantities, and line balancing is consistent with lean flow as it balances the workload (Womack and Jones, 1996; Supsomboon, 2019). These strategies are complementary and enhance responsiveness and flexibility of operations which are the most important behaviors of manufacturing performance.

RBV contributes these relationships in terms of strategic matters whereby scheduling and balancing are considered to be firm specific capabilities that improve efficiency and competitiveness. Skills to effectively coordinate resources, time and the human workforce is an internal resource that is of value and hard to duplicate by competitors (Barney, 1991; Aliyu et al., 2024). The practices, in turn, make sustainable manufacturing performance based on internal strengths and not on external factors.

Further, Mohammed and Lawal (2023) established that the digital integration of scheduling and balancing processes in line with RBV can be sustained to achieve sustainability in competitiveness benefits of African SMEs, particularly in resource limited situations.

Figure 2. Theoretical Integration Linking TOC, Lean Manufacturing, and RBV with Production Scheduling (IV1), Line Balancing (IV2), and Manufacturing Performance (DV).



Source: *Adapted from Goldratt (1990); Womack & Jones (1996); Barney (1991); Aliyu, Abubakar, & Suleiman (2024); Hillali, Ait Laachir, & Bennani (2025).*

The theoretical connection between all the three variables, as depicted in Figure 2, establishes how the theories of TOC, Lean Manufacturing, and RBV theories intersect to explain the relationship between Production Scheduling and Line Balancing and the Manufacturing Performance.

2.3 Empirical Review

Empirical research has made a contribution to the extent to which production scheduling, line balancing and manufacturing performance are related. Fathi et al. (2018) and El Machouti et al. (2024) globally have shown that the more sophisticated scheduling algorithms and AI-based systems are, the higher the productivity and throughput of industrial systems are. On the same note, Sheu and Chen (2008) emphasized here that forward and backward scheduling systems reduce the lead times and enhance delivery reliability.

Within the African and developing-economic environment, Aliyu et al. (2022, 2023, 2024) have carried out extensive studies of the manufacturing companies in West Africa, which demonstrated that integrated scheduling and balancing strategies enhance the efficiency, cost management, and resource allocation to a considerable degree. Their results highlight the relevance of the human factor and machine synchronization in the small and middle-scale industries.

Hillali et al. (2025) and El Abidine and Koltai

(2024) further discussed this debate with regard to Industry 5.0 systems, with a particular focus on synthesizing human skills and AI resources to create dynamic scheduling and an adaptive line balancing system. The authors of this study propose that real-time data integration leads to more resilient and flexible production-related aspects, which are crucial elements of contemporary manufacturing performance.

Comparative analysis of the methods reveals that previous studies (e.g., Falkenauer, 2005; Supsomboon, 2019) used a heuristic and simulation-based optimization, whereas recent ones (e.g., El Machouti et al., 2024; Hillali et al., 2025) use machine learning and multi-objective optimization to engage in real-time decision-making. In other parts of the world, African studies focus on the use of capacity and workforce balancing, but Western studies are concerned with automation and smart scheduling.

To conclude, it is empirically verified that the positive impact of production scheduling and line balancing on manufacturing performance is strong, but there are differences in the situations due to technological preparedness and human resources capacity.

2.4 Research Gap

Although the two areas of study have been studied extensively, there are still a number of gaps in both conceptual and empirical aspects when it comes to production scheduling and balancing an assembly line.

Conceptual Gaps: The available research, including the work of Fathi et al. (2018) and Qattawi and Chalil Madathil (2019), largely aimed at optimizing either of the two aspects of the scheduling or line balancing without providing any conceptual framework between the two. This fragmented strategy does not allow comprehending how their joint optimization can have a comprehensive impact on the performance of manufacturing. Moreover, the interplay of these variables in the wider framework of the modern manufacturing paradigms (e.g., lean production and digital transformation) is not well theorized.

Methodological Gaps: Most empirical studies have employed simulation or heuristic-based approaches (Haekal, 2021; Supsomboon, 2019) without investigating the mediating variable of the combination of scheduling and balancing to improve manufacturing performance through the use of resources or technological adjustment. In addition, it has led to a methodological gap in predictive and explanatory research designs due to the lack of integrated conceptual models that would combine both production scheduling and line balancing (El Machouti et al., 2024; El Abidine and Koltai, 2024).

Contextual Gaps: The majority of the previous research has been focused on the developed economies and automobile or electronic sectors (Sheu and Chen, 2008; Falkenauer, 2005). Empirical evidence is scarce in developing economies and in particular in the manufacturing industries in West Africa where contextual specifications like infrastructural constraints, skill differences, and rates of technology adoption play major roles in determining efficiency of production (Mohammed et al., 2023; Lawal et al., 2023). Therefore, the lack of geographical-specific conceptual studies predetermines the demand of frameworks that are flexible in various industrial and geographical situations.

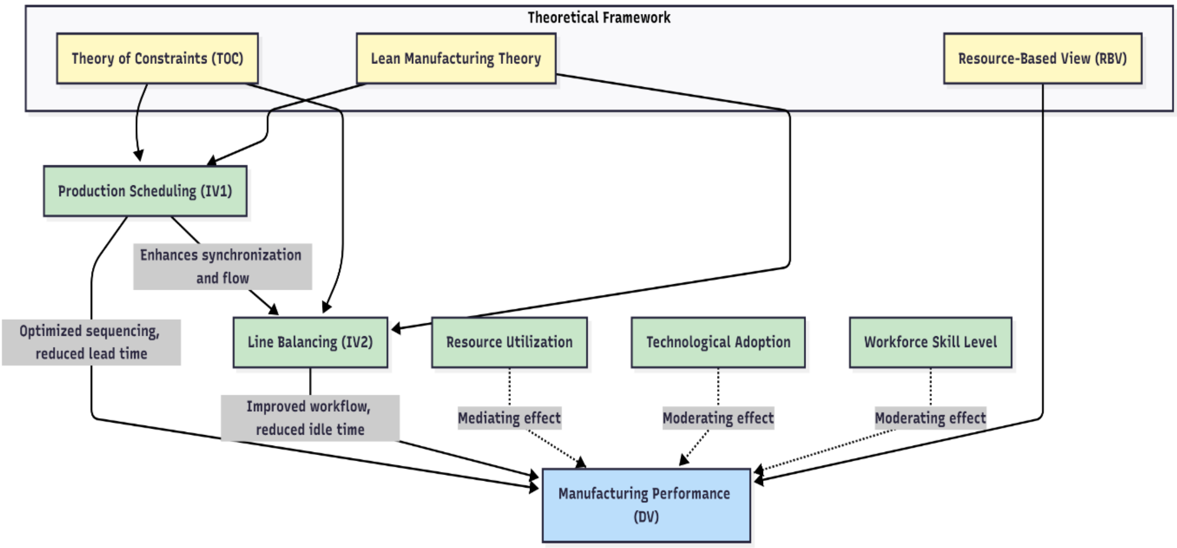
The Rationale of the Current Research: These gaps are covered in this conceptual study where an integrated model of the relationship between production scheduling and line balancing with manufacturing performance is proposed. The paper focuses on the applicability in the situation of developing economies, such as Nigeria, where the achievement of high efficiency, resource exploitation, and competitiveness can be achieved when both of these elements are optimized. This model would help in future empirical validation by quantitative and simulation based studies.

2.5 Conceptual Model of the Study

The conceptual model put forward (see Figure 3) shows the relationship between production scheduling (IV1) and line balancing (IV2) and manufacturing performance (DV). This model includes the concepts of the Theory of Constraints (TOC), the Lean Manufacturing Theory, and the Resource-Based View (RBV) in explaining the strategies of the internal operations that optimize performance outcomes.

- **Pathway A (IV1 → DV):** Due to efficient production planning, the throughput, lead time, and performance of giving on time deliveries are directly enhanced, which also results in performance.
- **Pathway B (IV2 → DV):** Efficient line balancing lowers the idle time and maximizes utilization and simplifies the workflow, enhancing efficiency and quality.
- **Pathway C (IV1 + IV2 → DV):** Combined with the completion of IV3, the balanced lines with optimized schedules increase the harmony of the production, decrease variability and costs.
- **Mediating/Moderating Factors:** These relationships may be moderated/mediated by resource utilization, technological uptake and workforce skill level as they have an effect on the effectiveness of production plans and line designs.

Figure 3. Conceptual Model Linking Production Scheduling, Line Balancing, and Manufacturing Performance



Source: *Developed by the researcher, adapted from Fathi et al. (2018); Haekal (2021); El Machouti et al. (2024); Mohammed et al. (2023); Hillali et al. (2025).*

In Figure 3, the conceptual model has combined the production scheduling and the line balancing as two strategic leverages, which affect the overall manufacturing performance. The model supposes that efficient production schedules (IV1) can contribute to the improvement of operations coordination, elimination of idle time, and delivery reliability, whereas the equitable distribution of workload and alleviation of the bottlenecks in the production line are the concerns of effective line balancing (IV2). These two operational factors interrelate each other to come up with a synergistic effect that encourages greater throughput, reduced costs of production and enhanced processes flexibility.

Moreover, the model has mediating and moderating variables to model the complexity of manufacturing environments. Resource utilization is postulated as a mediating variable that directs the impact of scheduling and balancing into performance outcomes that are measurable and the impact of technological adoption and the skill level of the workforce is postulated to moderate either bringing the relationships together or dissipating them based on the readiness of the organization. It is theoretically based on the Theory of Constraints (TOC), which is concerned with point of weaknesses in the system, their elimination; the Lean Manufacturing Theory, which aims at minimizing waste and maximizing flow; and the Resource-Based View (RBV), which views internal capabilities, such as scheduling and balancing as something unique that can be used to maintain competitiveness.

Simply put, the model supports an integrated production management philosophy where operational strategies are not studied in a vacuum but rather as complementary mechanisms in supporting sustainable manufacturing performance especially in the environment that is resource limited like in the case of developing economies.

3.0 Research Methodology

3.1 Research Design and Approach

This research takes a conceptual research design in a bid to come up with a theoretically based model which explains the role of production scheduling and line balancing on manufacturing performance. Conceptual research designs are also applicable in studies where it is based on the accumulated theoretical and empirical research to produce new knowledge as opposed to gathering primary data (Snyder, 2019). The paper is exploratory and integrates available theories, that is, the Theory of Constraints (TOC), Lean Manufacturing Theory, and the Resource-Based View (RBV) to make up the whole picture of manufacturing optimization.

This study has developed relationships and propositions that can be used in future empirical testing by critically examining scholarly articles published in Scopus, Web of Science, Science Direct and Emerald Insight. The study design focuses on analytical thinking and theoretical combination instead of numerical corroboration, which is consistent with other conceptual modelling studies in industrial engineering (El Machouti et al., 2024; Fathi et al., 2018).

3.2 Nature of the Conceptual Study

This is a conceptual paper, not an empirical one. It is based on the synthesis of secondary data and theoretical knowledge of the available scholarly publications, instead of field information or experiments. Conceptual studies enable the researcher to solve complicated associations among constructs by joining theories and discovering gaps in literature (Jaakkola, 2020).

The research constructs a conceptual bridge between production scheduling (IV1), line balancing (IV2) and manufacturing performance (DV) by linking fragmented research strands of manufacturing operations, production optimization, and organization performance. It is aimed at obtaining logical relationships and pathways instead of hypothesis testing. In such a way, it is a deductive approach, i.e., making conclusions based on theoretical and empirical data that can be found in previous literature (Aliyu et al., 2024; Hillali et al., 2025).

3.3 Sources of Data

Peer-reviewed journal articles, conference proceedings, and academic reports found in the reputable databases, including Scopus, Web of Science, ScienceDirect, Emerald Insight, and IEEE Xplore were used to obtain the secondary data of the study. The most recent of studies in the last five to twenty-five years were only taken into account to make sure they are relevant to today manufacturing settings.

Preference was put on the works that discussed the optimization of production, lean systems and efficiency of manufacturing. Significant works were by authors like Fathi et al. (2018), Supsomboon (2019), Qattawi and Chalil Madathil (2019), Haekal (2021), El Abidine and Koltai (2024), and Aliyu et al. (2024). The criteria of inclusion focused on the methodological rigor, theoretical background, and direct relevance to the production scheduling, line balancing, and manufacturing performance.

3.4 Analytical Approach

The thematic synthesis and conceptual modeling is the analytical approach of this conceptual study. Thematic synthesis is a method of identifying similarities and differences and classifying key themes that have been identified in reviewed literature, including optimization methods, performance indicators, and theoretical consistency (Thomas and

Harden, 2008).

These themes were subsequently combined to come up with a conceptual model (see Figure 3) that shows the relationship between scheduling, balancing, and performance improvement. Conceptual modelling enables the researcher to see the hypothetical relationships and causal channels and provides a conceptual basis upon which later empirical research can be conducted (Wacker, 1998; Snyder, 2019). This was done to achieve internal consistency, logical consistency, and conformity with the underlying theories (TOC, Lean, and RBV).

3.5 Limitations of the Conceptual Methodology

There are certain limitations associated with the conceptual methodology despite its strengths. The study is based on secondary literature only thus excluding the validation of primary data hence limits their ability to serve as empirical causality. The conclusions made in the study are theoretical and rely on the quality and the extent of literature reviewed. Moreover, a contextual difference including the industrial sector, level of technology and capability of the workforce might also influence the generalizability of the proposed model, particularly in developing world such as West Africa and Nigeria.

However, the conceptual approach has valuable directions that can be used in future empirical research, inviting scholars to substantiate and improve the suggested model through quantitative or mixed-methods research (Jaakkola, 2020; Hillali et al., 2025).

4.0 Findings of the Study

The following section introduces the conceptual results obtained by synthesizing the literature and the theories, as well as the model of the relationships between the production scheduling and line balancing and manufacturing performance developed. The research findings support the research questions and objectives as they indicate the relationship between these operational constructs in improving efficiency, productivity and competitiveness in manufacturing organizations.

4.1 Conceptual Findings on Production Scheduling

In theory, production plan became one of the critical factors of manufacturing effectiveness. The review of the literature demonstrates that properly developed scheduling systems are the most effective to allocate the resources and reduce the observable idle time as well as guarantee the stable production process (Fathi et al., 2018; Haekal, 2021; El Machouti et al., 2024). Scheduling performance is a direct factor that will lead to better throughput and reliability in delivery and minimized lead time, which will improve manufacturing performance (Hillali et al., 2025).

Moreover, when applied to the case of developing economies, including Nigeria, the issue of inefficient scheduling is usually caused by outdated planning, the absence of digitalization, and the scarcity of real-time data (Aliyu et al., 2024). In principle, scheduling is a strategic and operational lever, which converts the inputs in the form of resources into quantitative performance outputs by means of synchronization, task prioritization, and coordination of working processes. The model, therefore, determines scheduling as the first independent variable (IV1) that affects the dependent variable (DV) manufacturing performance) as a result of operational efficiency processes.

4.2 Conceptual Findings on Line Balancing

As observed in the review, line balancing is a very crucial factor in ensuring that human and machine utilization is optimized in production processes. By spreading the workload evenly, idle time, and bottlenecks are kept to the minimal, consequently, which improves the system throughput and the effectiveness of the equipment in general (Falkenauer, 2005; Supsomboon, 2019). Theoretically, balanced production lines will help to make operations leaner, minimizing the non-value-adding processes and increasing uniformity of the workflow (El Abidine and Koltai, 2024).

The results further suggest that the ability to balance the lines successfully requires technological assistance, flexibility of operators, and information-based planning, which tends to be immature in West African industries. Therefore, line balancing (IV2) is not a technical process but a strategic approach to management that is a direct contributor to sustainable performance (Mohammed et al., 2023). In theory, it serves as a complement technique to scheduling, which is focused on alignment of workforce abilities and equipments.

4.3 Integrated Findings on Manufacturing Performance

Combined analysis of the two independent variables indicates a significant conceptual connection with the performance of manufacturing, which is marked by the enhancement of productivity, quality, reduction of costs, flexibility, and the performance of delivery. A synergistic effect realized through production scheduling and line balancing helps organizations to produce the maximum output and reduce wastages (Qattawi and Chalil Madathil, 2019; Sheu and Chen, 2008).

Resource utilization is the conceptual variable of the study, which transforms scheduling and balancing efforts into real performance results as a mediating variable. In the meantime, these relationships are moderated by the use of technology and the level of skills in the workforce which increases the speed, accuracy and consistency of the production processes. Simply, the performance of manufacturing will be enhanced when the organizations combine scheduling accuracy and balanced production lines into a digitally empowered and skilled operations platform.

4.4 Summary of the Conceptual Model Outcomes

The theoretical assumptions are supported by the conceptual model based on Theory of Constraints (TOC), Lean Manufacturing and Resource-Based View (RBV). TOC is focused on locating and eliminating bottlenecks of the scheduling and balancing processes; Lean theory is focused on enhancing flow and minimizing waste; and RBV is focused on the internal operational resources as the sources of competitive advantage of their own.

Conceptually, the research concludes that:

1. Production scheduling streamlines the flow of time and resources and generates efficiency in the output.
2. Line balancing makes the distribution of tasks fair and enhances better utilization and stability of the workflow.
3. The combination of them results in better manufacturing performance through shorter lead times, lowering costs and flexibility.
4. These relationships are mediated and enhanced by resource utilization, technological adoption and level of skills, particularly in a resource constrained environment like in Nigeria.

All these findings taken together address the research objectives and answer the research questions since they show how internal operational strategies together can increase the competitiveness and sustainability of manufacturing as they are aligned.

5.0 Recommendations of the Study

Regarding the synthesis of the concepts, the following recommendations are suggested to manufacturing practitioners, researchers, and policymakers to lead to the implementation and future research.

5.1 Recommendations for Manufacturing Practitioners

1. Implement combined scheduling and balancing with advanced planning and scheduling (APS) software to coordinate the operations and eliminate the bottlenecks.
2. Introduce continuous improvement programs based on the lean methodology to maintain the balanced flow of production and remove the non-value activities.
3. Invest in training and development of cross functional skills in the workforce, flexibility in assigning tasks and able to adjust with production change.
4. Use Industry 4.0 technology including the IoT sensors, digital twins, and predictive

analytics to improve the balance adjustments and real-time scheduling.

5. Keep track of performance indicators (lead time, OEE and throughput) on a regular basis to determine the effectiveness of scheduling and balancing initiatives.

Through these recommendations, the firms, especially in Africa and Nigeria will be able to shift their reactive scheduling practice to proactive performance management systems.

5.2 Recommendations for Researchers

1. The conceptual model should be empirically tested by future researchers by utilizing quantitative research design approaches like Structural Equation Modeling (SEM) to ascertain the cause related to the variables.
2. Comparisons of various industrial sectors and areas should be carried out to evaluate contextual variations in scheduling-balancing effects.
3. Mediating variables that need to be investigated by the researchers include technology integration, collaboration over the supply chain, and workforce engagement to extend the model.
4. Use longitudinal designs to measure changes in the effects of process optimization on performance outcomes in the long-term.

5.3 Recommendations for Policymakers

1. Governments are advised to promote the policies of digitalization of industries in support of automation, smart manufacturing, and smart schedules in the local industries.
2. Production optimization and lean programs should form the focus of technical education and vocational training programs that create skilled manpower.
3. Create manufacturing innovation centers and government-business relations that will allow SMEs to access scheduling and balancing technologies.
4. Implement taxes rebates on companies that implement smart production systems as incentives to process improvement.

These will improve the national industrial productivity and competitiveness in national and global value chains.

5.4 Suggestions for Future Research

1. Empirical research in the future should construct tests on what the moderations of technological adoption and skill level are based on real manufacturing datasets.
2. The model can be generalized to other fields besides manufacturing such as service operations or supply chain to determine the generalizability of the model.
3. The additional conceptual development might be to bring the sustainability aspects (energy efficiency, environmental performance) into the framework.
4. The cross-country analysis in Africa and emerging countries is suggested to investigate the contextual variation in the scheduling-balancing relationships.

This kind of research would help in the development of theory in addition to offering practical implications to academicians and practitioners.

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