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THE SYNERGISTIC RELATIONSHIP BETWEEN PRODUCTION SCHEDULING AND PRODUCTION LINE BALANCING IN ENHANCING OPERATIONAL PERFORMANCE: AN APPLIED STUDY AT SAMARRA PHARMACEUTICAL FACTORY

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Abstract. This study investigates the synergistic relationship between production scheduling and production line balancing in enhancing operational performance at Samarra Pharmaceutical Factory. The research addresses an important gap in production and operations management literature, where scheduling and line balancing are often examined as separate operational practices despite their practical interdependence in pharmaceutical manufacturing. A quantitative, field-based research design was adopted, and data were collected through a structured bilingual questionnaire distributed to employees, supervisors, and managers working in different functional areas of the factory. The final sample consisted of 43 valid responses. Production scheduling, production line balancing, operational performance, and scheduling–line balancing integration were measured using multi-item Likert scales. The data were analyzed using reliability analysis, descriptive statistics, Pearson correlation, and regression-based hypothesis testing. The findings show excellent internal consistency for all constructs, with Cronbach's Alpha values ranging from 0.929 to 0.976. The results reveal that production scheduling has a significant positive effect on operational performance, while production line balancing demonstrates a stronger positive effect. The combined regression model explains 67.3% of the variance in operational performance, and the moderation model explains 69.5%. However, the interaction term between production scheduling and production line balancing is not statistically significant at the 0.05 level. These findings suggest that the synergistic value of the two practices appears mainly through their complementary direct effects and operational integration rather than through a formal moderation effect. The study offers practical implications for improving scheduling responsiveness, reducing bottlenecks, minimizing idle time, and strengthening coordination between scheduling and line-balancing decisions.

Keywords: Production scheduling; Production line balancing; Operational performance; Pharmaceutical manufacturing; Operations management; Scheduling integration; Samarra Pharma-ceutical Factory.

Introduction

Many manufacturing organizations now need to manage time, capacity, quality, cost, and flexibility simultaneously rather than as separate operational concerns. This pressure becomes more critical in pharmaceutical manufacturing because production decisions are not limited to converting inputs into finished products, but also involve product availability, regulatory discipline, batch integrity, equipment readiness, material flow, documentation requirements, and quality-control processes. Operations management, in this context, offers a managerial and analytical basis for the design, planning, scheduling, control, and improvement of systems through which goods and services are produced [1], [2], [3], [4]. Accordingly, the effectiveness of operational
decisions depends not only on the effectiveness of individual practices but also on the degree of integration among planning, scheduling, workload distribution, process control, and performance-improvement activities.

Production scheduling is one of the central decision areas that are crucial in short-term production and operations management. It determines what is produced, when production should start and finish, which resources should be assigned, and how jobs or batches should be sequenced across departments, machines, or production lines. A production schedule is therefore not just a timetable; it is also a coordination mechanism that links demand requirements, capacity constraints, workforce availability, machine status, material readiness, maintenance windows, and delivery commitments [5], [6]. Recent scheduling literature emphasizes that modern manufacturing systems require schedules that are feasible, responsive, resource-aware, and capable of adapting to disruptions in materials, machines, labor, and customer requirements [7], [8]. Therefore, effective production scheduling can enhance operational performance by reducing waiting time, limiting idle production capacity, improving order completion, supporting delivery reliability, and improving the utilization of productive resources.

It should be noted that production scheduling is not enough to ensure high operational performance if the production line is poorly balanced. Production line balancing is the process of assigning tasks, workloads, operators, and processing times across workstations to minimize idle time and bottlenecks and achieve a smoother production flow. In manufacturing systems, an imbalanced production line can lead to excessive waiting before some stations, underutilization at others, longer cycle times, higher work-in-process inventory, and lower overall productivity [9], [10]. Studies involving empirical and simulation analyses indicate that production line balancing can improve productivity, line efficiency, labor utilization, and output flow when work elements are distributed more effectively across stations [11], [12]. As a result, line balancing should be seen as a managerial practice that directly supports operational efficiency, cost control, quality stability, and production responsiveness rather than as a narrow technical arrangement of workstations.

The connection between production scheduling and production line balancing is particularly important because the two practices are mutually reinforcing. A well-designed production schedule may lose much of its value if jobs are released into an imbalanced production line characterized by bottlenecks, idle time, and uneven workloads. Similarly, a properly balanced production line may fail to achieve its expected benefits if orders are poorly sequenced, the required materials are unavailable, machine priorities are unclear, or the schedule is frequently changed without coordination. The close relationship between the two practices represents a higher level of operational integration, in which timing and workload-distribution decisions
reinforce each other. This view is consistent with the contemporary understanding of operations management, which emphasizes that capacity, process design, flow control, and performance objectives should be aligned rather than managed as disconnected activities [3], [2], [4].

The need for such integration becomes more evident in pharmaceutical manufacturing. Pharmaceutical plants normally operate under stringent production, storage, documentation, and quality requirements. Scheduling and balancing challenges arise from batch production, cleaning procedures, equipment preparation, material release, quality-control checks, and product-specific processing requirements. Poor scheduling can result in delays, overtime, capacity conflicts, and inefficient machine use, while weak line balancing can increase cycle time, result in station-level congestion, and reduce the smoothness of production flow. Recent studies on pharmaceutical production planning and scheduling emphasize the importance of constraint-aware, data-driven, and resource-sensitive approaches for improving makespan, tardiness, production stability, and manufacturing responsiveness in drug-production environments [13], [14]. This indicates that, along with accurate scheduling practices, pharmaceutical plants also need balanced production lines capable of absorbing planned workloads efficiently.

The Samarra Pharmaceutical Factory serves as a relevant applied setting for examining this relationship. As an Iraqi pharmaceutical manufacturing organization, it operates in a sector where operational performance is linked to the availability of essential medicines, the efficient utilization of industrial resources, and the ability to maintain production continuity under operational and market pressures. The official website of the State Company for Drugs Industry and Medical Appliances/Samarra presents the company through its products, industrial facilities, quality policy, production activities, and institutional communication channels, indicating its operational role within the Iraqi pharmaceutical industry [15]. Thus, examining production scheduling, production line balancing, and operational performance in this manufacturing facility can provide practical insights for improving manufacturing effectiveness in a strategically important industrial context.

Operational performance in manufacturing is typically viewed from a multidimensional perspective rather than evaluated through a single financial or output-based indicator. These dimensions include productivity, cost efficiency, quality, delivery reliability, flexibility, lead-time reduction, resource utilization, and process efficiency [16], [17], [18]. From an operations-management perspective, these dimensions reflect how effectively an organization converts inputs into outputs with minimum waste, acceptable quality, reliable timing, and sufficient responsiveness to changing conditions. Operational performance is treated as the dependent variable in this study because it represents the final outcome expected from improving production scheduling and production line balancing. Better schedules are expected to improve timing, resource allocation, and order completion, while better line balancing is expected to improve workflow, reduce bottlenecks,and increase line efficiency. More importantly, when both practices are coordinated, their combined effect may be stronger than the isolated effect of either practice.

Despite the extensive literature on production scheduling and assembly-line or production-line balancing, many studies still address these two areas as separate technical problems. Scheduling studies focus on sequencing rules, optimization models, flexible job-shop problems, resource scheduling, and intelligent or digital scheduling methods [19], [20], [21]. In contrast, line-balancing studies tend to focus on workload allocation, station design, ergonomic considerations, balance delay, and line efficiency [9], [10]. These research streams have advanced the technical understanding of scheduling and balancing, but fewer empirical studies have examined how the managerial interaction between production scheduling and production line balancing contributes to operational performance, particularly in pharmaceutical manufacturing and within the Iraqi industrial environment. This gap is important because operational performance in such settings depends not only on the existence of scheduling or balancing practices, but also on the degree to which these practices are aligned and mutually supportive.

Therefore, this research aims to investigate the synergistic relationship between production scheduling and production line balancing in improving operational performance at Samarra Pharmaceutical Factory. The study is predicated on the idea that production scheduling and line balancing are complementary mechanisms that work together to affect productivity, efficiency, delivery reliability, quality, cost control, and flexibility rather than being separate operational practices. By developing a field-based empirical model, the study seeks to identify the key dimensions of production scheduling and production line balancing, quantify their direct and interactive effects on operational performance, and offer evidence-based recommendations that could help production managers improve operational outcomes. By extending empirical evidence to the Iraqi pharmaceutical manufacturing context and connecting two fundamental operational practices within a single applied framework, the study contributes to the production and operations management literature.

Literature Review

Operational performance is rarely enhanced by a single managerial practice, according to the literature on production and operations management. Instead, a number of operational decisions, especially those pertaining to capacity, sequencing, workload distribution, resource usage, and process flow, need to be aligned in order to improve performance. Production scheduling and production line balancing are seen as two closely related mechanisms. While line balancing determines whether the production line can handle these planned workloads without excessive idle time, bottlenecks, or flow interruptions, scheduling establishes thetiming and order of production activities. As a result, the relationship between the two variables should be investigated not only as a technical relationship, but also as a managerial interaction that could influence operational performance outcomes.

Production scheduling has been given considerable attention in recent operations management literature because of its direct effect on manufacturing responsiveness, resource utilization, lead time and delivery reliability. Chen et al reviewed production planning and scheduling approaches within the framework of Industry 4.0 and noted that manufacturing systems increasing require scheduling methods that can respond to variability, demand changes, and resource constraints [5]. Similarly, Geurtsen et al. stated that the production, maintenance and resource scheduling are interdependent decision areas, especially when the availability of equipment and maintenance windows affect the continuity of production [7]. Dauzère-Pérès et al. also showed that flexible job-shop scheduling is still a key research area as current production environments must deal with several machines, routes and operational constraints [19]. These studies indicate that the effectiveness of scheduling can be reflected in schedule adherence, sequencing efficiency, resource allocation, lead-time control, and responsiveness to disruptions.

Line balancing has also been widely discussed and is a key mechanism for improving manufacturing flow. Boysen et al. provided a comprehensive review of assembly line balancing research and showed that balancing decisions affect the allocation of tasks across stations, the reduction of idle time, and the achievement of efficient line flow [9]. This discussion was extended by Abdous et al. who included ergonomic considerations into line balancing. They showed that the effectiveness of workload distribution depends not only on technical task allocation but also on the human and operational conditions under which the work is performed [10]. Recent studies also support the practical value of line balancing in terms of improving productivity, line efficiency and labour utilization. For example, Teshome et al. used simulation modelling to improve productivity by balancing the assembly line while Hlyal and El Machouti highlighted the dynamic nature of balancing when taking into account operator skills and quality outcomes [11], [12]. Line balancing, thus, can be viewed as a multidimensional operational practice that involves workload distribution, bottleneck reduction, cycle time alignment, idle time reduction, and station utilization.

Despite the fact that production scheduling and line balancing are frequently examined independently, several recent research indicate that taking them into account together is more consistent with actual manufacturing conditions. Production schedules become more effective when they are connected to the availability and movement of necessary resources, according to Liang et al.'s analysis of the integrated scheduling of production and material delivery in intelligent manufacturing systems [21]. Singh et al. emphasized the expanding use of digital twins and artificial intelligence in production scheduling, especiallyfor improving the adaptability of scheduling decisions in complex manufacturing systems [20]. According to Sitahong et al., production line balancing has evolved from a traditional task-allocation issue to a more comprehensive system integration, where balancing is linked to flexibility, digitalization, sustainability, and production-system coordination [22]. These advancements lend credence to the idea that scheduling and balancing should be viewed as complementary

practices rather than isolated operational tools.
The relevance of this integrated view is further supported by empirical and applied research in pharmaceutical manufacture. Batch processing, cleaning and setup requirements, quality-control holds, documentation constraints, and stringent compliance processes are typical characteristics of pharmaceutical manufacture. Because of these circumstances, line balancing and scheduling are especially crucial. By redesigning production scenarios and addressing operational inefficiencies, Maaboud et al.'s study on process optimization in pharmaceutical production demonstrated how modeling and simulation could significantly increase line productivity [23]. Additionally, Michno and Michno stressed that resource constraints, regulatory requirements, and production-flow stability must all be carefully taken into account when planning and scheduling pharmaceutical production [13]. Using the Samarra Drug Industry as a case study, Naser et al. employed discrete-event simulation in a directly relevant Iraqi context to identify production bottlenecks, shorten cycle times, control work-in-process, and increase throughput without sacrificing regulatory compliance [24]. Because it demonstrates that the Samarra Drug Industry has operational issues with bottlenecks, cycle time, resource utilization, and production-flow improvement, this study is especially important for the current research.
The dependent outcome that can be used to assess the effectiveness of scheduling and line balancing is operational performance. Previous studies have commonly assessed operational performance through productivity, quality, cost, delivery reliability, flexibility, process efficiency and resource utilization. Prabhu et al. [16] discussed competitive operational priorities in manufacturing companies and stressed that the performance dimensions of cost, quality, delivery, and flexibility are essential. According to Panigrahi et al. [17], lean manufacturing practices have a positive impact on operational and business performance, particularly when waste reduction and process efficiency are improved. In the pharmaceutical industry, AlDmour et al. [25] analyzed Jordanian pharmaceutical manufacturing companies and found that lean six sigma practices have a positive impact on the dimensions of operational performance, including flexibility, quality, and cost. The present study uses operational performance as a multidimensional dependent variable, which is supported by these findings.
Production scheduling and production line balancing have a synergistic relationship, according to the reviewed literature. While efficient line balancing ensures that these orders move through the production system with fewer bottlenecks, less idle time, and smoother workload distribution, effective scheduling enhances the timing, sequencing, and allocation of production orders. The production system is better able to increase throughput, decrease delays, improve resource utilization, stabilize quality, and control costs when the two practices are aligned. Throughput rate, line efficiency, smoothness index, and resource utilization are all impacted by the integration of production scheduling and line balancing, A recent conceptual study by Chiroma et al. showed that [26]. Nevertheless, there is still a lack of research on this link in applied pharmaceutical settings, particularly in Iraq through field-based empirical studies.
As highlighted in the above discussion, a more targeted research gap can be formulated around the limited empirical examination of scheduling–line balancing integration in pharmaceutical manufacturing, particularly in the Iraqi context. The gap is clarified in the next section, Where the conceptual model and hypotheses of the present study are developed.

Research Gap

The reviewed literature shows that production scheduling and production line balancing have been extensively studied as important operational practices in manufacturing systems. Studies on production scheduling have mainly focused on sequencing rules, resource allocation, production responsiveness, lead-time reduction, and the application of intelligent or digital scheduling approach. Likewise, production line balancing studies have been mainly concerned with workload distribution, bottleneck reduction, cycle time alignment, idle time reduction and workstation utilization. Although these studies provide valuable technical and managerial insights, much of the existing literature continues to examine scheduling and line balancing as separate operational issues.
This division creates an important research gap. Decisions on scheduling and line balancing

are closely connected in actual manufacturing settings, particularly in pharmaceutical production. If there are bottlenecks, idle time, or uneven workload distribution on the production line, a production schedule might not produce the desired outcomes. Similarly, if production orders are poorly sequenced, resources are not allocated appropriately, or schedules are frequently changed without coordination, a balanced production line may not effectively improve operational performance. Thus, operational performance depends not only on the existence of scheduling and line-balancing practices, but also on the degree of alignment and synergy between them.

Furthermore, the literature provides limited empirical evidence regarding how production scheduling and production line balancing interact to improve operational performance in pharmaceutical manufacturing, especially in the industrial context of Iraq. Limited field-based research has examined managers' and employees' perceptions of the combined role of scheduling and line balancing in improving operational performance at Samarra Pharmaceutical Factory, despite the fact that prior applied studies have looked at production improvement and bottleneck reduction in pharmaceutical settings. Accordingly, to address this gap, the current study develops and tests an empirical model that connects production scheduling, production line balancing, and their interaction with operational performance.

Conceptual Research Model

The current study's conceptual model is predicated on the idea that production scheduling and production line balancing are the two primary independent variables that influence operational performance in pharmaceutical manufacturing. Production scheduling refers to the factory’s ability to organize, sequence, allocate, and control production activities according to available resources and operational requirements. Production line balancing refers to the factory’s ability to distribute workloads effectively across workstations, reduce bottlenecks, minimize idle time, and maintain a smooth production flow.

Operational performance represents the dependent variable and reflects the factory’s ability to achieve productivity, operational efficiency, quality, delivery reliability, cost control, and flexibility. In addition to the direct effects of production scheduling and production line balancing, the model assumes that production line balancing strengthens the effect of production scheduling on operational performance. In other words, the benefits of scheduling are expected to be greater when production lines are effectively balanced.

Accordingly, the conceptual model includes the following relationships:

1. Production Scheduling → Operational Performance
2. Production Line Balancing → Operational Performance
3. Production Scheduling × Production Line Balancing → Operational Performance

In this model, production scheduling and production line balancing are treated as independent variables, operational performance is treated as the dependent variable, and the interaction between production scheduling and production line balancing represents the synergistic effect examined in this study.

Hypotheses Development

Production scheduling is expected to have a positive effect on operational performance because effective scheduling improves the timing, sequencing, and coordination of production activities.The factory becomes more capable of reducing delays, improving resource utilization, controlling lead time, and meeting production targets when production schedules are accurate, flexible, and aligned with resource availability. Therefore, the first main hypothesis is formulated as follows:

Accurate, flexible production schedules aligned with resource availability makes the factory more capable to reduce delays, improve utilization of resources, control the lead time and meet the production targets. Hence the first main hypothesis is formulated as follows:

H1: The effect of production scheduling on operational performance at Samarra Pharmaceutical Factory is positive and statistically significant.

The following dimensions were used to operationalize production scheduling rather than being tested as separate hypotheses:

D1: Schedule adherence and accuracy.

D2: Sequencing and dispatching effectiveness.
D3: Resource allocation and capacity utilization.
D4: Schedule flexibility and rescheduling responsiveness.
D5: Lead-time and tardiness control.
Additionally, production line balancing is anticipated to have a positive effect on operational performance. Reducing bottlenecks, minimizing idle time, enhancing workflow, increasing labor and workstation utilization, and supporting smoother production movement are all possible with a balanced production line. These enhancements have a direct bearing on cost reduction, quality stability, productivity, efficiency, and delivery reliability. Therefore, the second main hypothesis is formulated as follows:
H2: Production line balancing has a statistically significant positive effect on operational performance at Samarra Pharmaceutical Factory.
The following dimensions were used to operationalize production line balancing rather than being tested as separate hypotheses:
D6: Workload distribution among workstations.
D7: Bottleneck reduction.
D8: Idle-time and balance-delay reduction.
D9: Cycle-time alignment.
D10: Workstation and labor utilization.
Additionally, research indicates that production scheduling and production line balancing shouldn't be viewed as isolated practices. Because balanced production lines are necessary for effective schedules, and balanced lines need coordinated schedules to realize their anticipated performance gains, their alignment may have a synergistic effect. The factory is expected to achieve increased productivity, smoother flow, higher delivery reliability, better resource utilization, and stronger operational efficiency when scheduling and line-balancing decisions are mutually supportive. Therefore, the third hypothesis is formulated as follows:
H3: At Samarra Pharmaceutical Factory, the relationship between production scheduling and operational performance is positively moderated by production line balancing, meaning that the effect of production scheduling on operational performance because stronger as production line balancing becomes more effective.

Methods

Research Design

This study adopted a quantitative, field-based, and explanatory research design to examine the synergistic relationship between production scheduling and production line balancing in enhancing Samarra Pharmaceutical Factory's operational performance. Because the study's objectives were to measure employees' and managers' perceptions of clearly defined operational practices and to test statistically formulated relationships among the research variables, the quantitative approach was deemed appropriate. In this way, the study goes beyond a purely descriptive analysis and seeks to explain how production scheduling and production line balancing affect operational performance both independently and collectively.
The research design was cross-sectional, as the data were collected at a single point in time from respondents who worked in various functional areas pertaining to planning, production, quality, maintenance, administration, and other operational functions. When the goal of applied operations-management research is to capture current managerial and operational perceptions within a particular industrial setting, this design is appropriate. The Samarra Pharmaceutical Factory provides a relevant context for investigating scheduling, workload distribution, bottleneck reduction, and operational performance in pharmaceutical manufacturing.

Population and Sample

The target population consisted of employees, supervisors and managers at Samarra Pharmaceutical Factory. The respondents were selected on the basis of their expected familiarity with production activities, scheduling practices, production line operations, quality requirements, and general operational performance issues. Respondents from production-related and support departments were included to gain a broader field-based understanding of the research problem because the study focuses on operational practices inside the factory. A total of 43 valid responses were collected and analyzed. Before completing the questionnaire, each respondent indicated their willingness to participate in academic study. Thus, 43 valid cases made up the final sample. The sample size was deemed appropriate for the exploration and applied nature of the statistical procedures used in this study and reflects the practical challenges of gathering field data from a specialized pharmaceutical manufacturing environment.

Data Collection Procedure

Primary data were collected by means of a structured questionnaire specifically designed for the objectives of the present study. The questionnaire was prepared in both English and Arabic to make it clear and accessible to respondents with different levels of language proficiency. The bilingual structure contributed to reducing misunderstandings and increasing the likelihood of respondents answering based on their actual experience rather than on difficulties in interpreting the language.

Potential respondents who worked at Samarra Pharmaceutical Factory received the questionnaire electronically. Respondents were told that their responses would only be used for scholarly research, and participation was entirely voluntary. Respondents were encouraged to be honest because the questionnaire did not ask for personally identifiable information. Following data collection, the responses were examined to make sure they were complete, consistent, and appropriate for statistical analysis.

Measurement Instrument

The questionnaire was developed based on the study's conceptual model and hypotheses. It consisted of five main sections. The first section collected demographic and employment-related information, namely gender, age groups, educational qualifications, years of experience, job position and department or work area. These questions were included to describe the sample and to better understand the respondents' background.

The second section measured Production Scheduling, which was the first independent variable. Ten items coded from PS1 to PS10 were used to measure this construct. The construct comprised five dimensions: lead-time and tardiness control; resource allocation and capacity utilization; sequencing and dispatching effectiveness; schedule flexibility and rescheduling responsiveness; and schedule accuracy and adherence.

The third section assessed Production Line Balancing, the second independent variable. Ten items coded from PLB1 to PLB10 were used to measure this construct. These items covered workstation and labor utilization, cycle-time alignment, idle-time and balance-delay reduction, bottleneck reduction, and workload distribution among workstations The fourth section measured the dependent variable, *Operational Performance*. This construct was measured through twelve items coded from OP1 to OP12. The items captured multiple operational-performance dimensions, including productivity, operational efficiency, quality performance, delivery reliability, cost performance, and operational flexibility.

The fifth section measured *Scheduling–Line Balancing Integration*. This construct was measured through four items coded from SLI1 to SLI4. It was included to capture the degree of coordination between production scheduling and production line balancing. Although the main statistical interaction was tested through an interaction term, this section provided an additional descriptive and correlational indication of how respondents perceived integration between the two operational practices.

All measurement items were assessed using a five-point Likert scale, where 1 represented "strongly disagree" and 5 represented "strongly agree". The use of a five-point Likert scale was appropriate because the study measured respondents' perceptions regarding the presence and effectiveness of operational practices inside the factory.

Operationalization of Variables

The variables of the study were operationalized by calculating the arithmetic mean of the items belonging to each construct. This procedure enabled the conversion of individual questionnaire items into composite variables that could be used for reliability testing, descriptive analysis, correlation analysis and regression analysis.

The main variables were computed as follows:

1. Production Scheduling = Mean of PS1–PS10
2. Production Line Balancing = Mean of PLB1–PLB10
3. Operational Performance = Mean of OP1–OP12
4. Scheduling–Line Balancing Integration = Mean of SLI1–SLI4

In addition, the interaction effect was calculated to test the synergistic relationship between production scheduling and production line balancing. Before calculating the interaction term, the main independent variables were mean-centered in order to reduce potential multicollinearity and to improve the interpretability of the interaction model. The interaction term was calculated as follows:

$$Interaction = (PS - \bar{PS}) \times (PLB - \bar{PLB})$$

where PS represents production scheduling and PLB represents production line balancing. This interaction term was used to examine whether production line balancing strengthens the relationship between production scheduling and operational performance.

Data Analysis Techniques

The statistical analysis was conducted in several stages. First, the dataset was screened to ensure that all valid responses were included and that the measurement items were properly coded according to the five-point Likert scale. Responses to demographic questions were analyzed using frequencies and percentages to describe the characteristics of the sample.

Second, reliability analysis was conducted using Cronbach's Alpha to assess the internal consistency of the measurement scales. Reliability was examined for the four main constructs: production scheduling, production line balancing, operational performance, and scheduling–line balancing integration. High reliability coefficients indicate that the items within each construct consistently measure the same underlying concept.

Third, for the key constructs and their items, descriptive statistics were calculated. The mean and standard deviation were used to evaluate the general level of respondents' perceptions. Stronger agreement with the existence or efficacy of the operational practice being assessed was indicated by higher mean scores.

Fourth, Pearson correlation analysis was used to examine the strength and direction of the relationships among the main study variables. Correlation analysis was particularly useful for assessing whether production scheduling, production line balancing, and scheduling–line balancing integration were positively associated with operational performance.

Fifth, regression analysis was used to test the research hypotheses. Simple linear regression was applied to test the direct effect of production scheduling on operational performance and the direct effect of production line balancing on operational performance. Multiple regression was then used to examine the combined contribution of production scheduling and production line balancing in explaining operational performance. Finally, moderation regression was used to test the interaction effect between production scheduling and production line balancing.

The direct-effect models were specified as follows:

$$OP = \beta 0 + \beta 1 PS + \varepsilon$$

$$OP = \beta 0 + \beta 1 PLB + \varepsilon$$

The combined model was specified as follows:

$$OP = \beta 0 + \beta 1 PS + \beta 2 PLB + \varepsilon$$

The moderation model was specified as follows:

$$OP = \beta 0 + \beta 1 PSc + \beta 2 PLBc + \beta 3 (PSc \times PLBc) + \varepsilon$$

where OP refers to operational performance, PS refers to production scheduling, PLB refers to production line balancing, PSc and $PLBc$ refer to the centered forms of the independent variables, and ε represents the error term.

Validity and Reliability Considerations

Several procedures were followed to strengthen the methodological quality of the study. Content validity was supported by developing the questionnaire items from the conceptual framework, the research hypotheses, and the operations-management literature discussed in the previous sections. The constructs and their dimensions were aligned with established themes in

production scheduling, production line balancing, and operational performance.
By minimizing potential issues with respondents' interpretation, the questionnaire's bilingual presentation further supported response validity. Additionally, the questionnaire structure proceeded logically from general demographic data to the key operational constructs. This enabled respondents to better understand the questions' context and provide more consistent answers as a result.
Cronbach's alpha was used to assess reliability. Because the study measured each construct using multi-item scales, the reliability analysis was crucial. Sufficient internal consistency indicates that the items within each scale are sufficiently coherent to be combined into composite variables for subsequent statistical analysis.

Ethical Considerations

The study followed fundamental ethical principles for academic field research. Respondents were asked to confirm their agreement before filling out the questionnaire, and participation was entirely voluntary. The study's purpose was clearly communicated, and the responses were kept confidential. Respondents were not asked for any personally identifiable information, and the collected data was used exclusively for academic analysis. These procedures helped ensure that the research was conducted responsibly and with respect to the participants' privacy.

Results and Discussion

Overview of the Statistical Analysis

The empirical results from the field survey at Samarra Pharmaceutical Factory are presented and discussed in this section. The methodological process outlined in the preceding section is followed in the analysis. To better understand the participants' backgrounds, the respondent profile is first summarized. Second, for the main constructs, reliability results and descriptive statistics are reported. Third, item-level findings are analyzed to identify the most and least strongly perceived operational practices. Fourth, the relationships among production scheduling, production line balancing, scheduling–line balancing integration, and operational performance are evaluated using Pearson correlation analysis. Lastly, regression analysis is employed to assess the direct and interaction effects suggested in the conceptual model as well as to test the research hypotheses.
The final dataset consisted of 43 valid responses. Every respondent confirmed their agreement to participate in the scholarly investigation. As a result, no responses were excluded because of consent-related issues. Production scheduling, production line balancing, operational performance, and scheduling–line balancing integration were the four key constructs whose composite scores were used for the analysis.

Respondent Profile

Table 1 summarizes the demographic and work-related characteristics of the respondents.. Male survey respondents made up 72.1% of the valid responses in the sample, while female respondents made up 27.9%. The largest age group, comprising 41.9% of the sample, was 45–54 years old. This suggests that a sizable percentage of responders were mature employees with accumulated work experience. 27.9% of respondents were between the ages of 35 and 44, and 20.9% were between the ages of 25 and 34. Only a small proportion of responders were below 25 years or 55 years and above.
Respondents were predominantly holders of bachelor's and master's degrees in terms of educational background. Bachelor's degree holders represented 37.2% had a bachelor's degree, and 34.9% had a master's. The majority of participants possessed an adequate academic background to comprehend the operational issues covered in the questionnaire, which increases the responses' credibility. In terms of work experience, 20.9% of respondents had 16–20 years of experience, and 37.2% had more than 20 years. This indicates that over half of the sample had extensive managerial or operational experience, which is advantageous for a field study that focuses on line balancing, production scheduling, and operational performance.
Additionally, the distribution of job positions shows a useful mix of technical and managerial viewpoints. Employees in quality control and middle management each made up 25.6% of the respondents. Senior management accounted for 11.6%, and production managers accounted

for 11.6%. Also represented were employees in planning or scheduling, maintenance, production
rvisors, production-line employees, and other roles. Production employees made up the largest group in terms of department or work area, representing 37.2% of the sample, followed by administration at 27.9% and quality control at 18.6%. Because it captures perceptions from respondents who are either directly or indirectly related to production flow, scheduling decisions, quality discipline, and operational outcomes, this composition is suitable for the objectives of the current study.

Table 1. Demographic and job profile of respondents

Variable	Category	Frequency	Percentage
Gender	Male	31	72.1%
	Female	12	27.9%
Age group	Less than 25 years	1	2.3%
	25–34 years	9	20.9%
	35–44 years	12	27.9%
	45–54 years	18	41.9%
	55 years and above	3	7.0%
Educational qualification	Diploma or less	5	11.6%
	Bachelor’s degree	16	37.2%
	Master’s degree	15	34.9%
	PhD	5	11.6%
	Other	2	4.7%
Years of experience	Less than 5 years	6	14.0%
	5–10 years	4	9.3%
	11–15 years	8	18.6%
	16–20 years	9	20.9%
	More than 20 years	16	37.2%
Job position	Senior management	5	11.6%
	Middle management	11	25.6%
	Production manager	5	11.6%
	Production supervisor	4	9.3%
	Quality control employee	11	25.6%
	Maintenance employee	1	2.3%
	Production line employee	2	4.7%
	Planning or scheduling employee	2	4.7%
	Other	2	4.7%
Department / work area	Production	16	37.2%
	Planning	2	4.7%
	Quality Control	8	18.6%
	Maintenance	2	4.7%
	Warehousing	1	2.3%
	Administration	12	27.9%

Variable	Category	Frequency	Percentage
	Other	2	4.7%

Reliability and Descriptive Statistics

Cronbach's alpha was used in reliability analysis to evaluate the measurement scales' internal consistency. All constructs achieved excellent reliability values, as Table 2 illustrates. An alpha value of 0.976 was recorded for production scheduling, 0.953 for production line balancing, 0.975 for operational performance, and 0.929 for scheduling–line balancing integration. These findings show that each construct's items are highly consistent and can be aggregated into composite variables for further statistical analysis.

The descriptive statistics also show that respondents generally reported positive perceptions toward the main operational practices examined in the study. Operational performance recorded the highest mean score (M = 3.864, SD = 0.931), followed by production line balancing (M = 3.830, SD = 0.809), scheduling–line balancing integration (M = 3.785, SD = 0.986), and production scheduling (M = 3.728, SD = 1.057). Since all mean values are above the midpoint of the five-point scale, the results suggest that the respondents perceived the factory as having a reasonably high level of operational practices and operational performance.

The relatively higher mean of operational performance indicates that respondents generally perceived that productivity, quality, delivery reliability, cost control, and flexibility were present to a meaningful degree. At the same time, the somewhat lower mean for production scheduling suggests that scheduling practices, while positive overall, may need to be given more managerial attention, particularly in the areas of responsiveness, adjustment to disruptions and control of delays. Figure 1 provides a visual profile of the constructs by combining mean, standard deviation, and reliability in one figure.

Table 2. Reliability and descriptive statistics of the main constructs

Construct	Items	Mean	SD	Cronbach's Alpha
Production Scheduling	PS1–PS10	3.728	1.057	0.976
Production Line Balancing	PLB1–PLB10	3.830	0.809	0.953
Operational Performance	OP1–OP12	3.864	0.931	0.975
Scheduling–Line Balancing Inte-gration	SLI1–SLI4	3.785	0.986	0.929

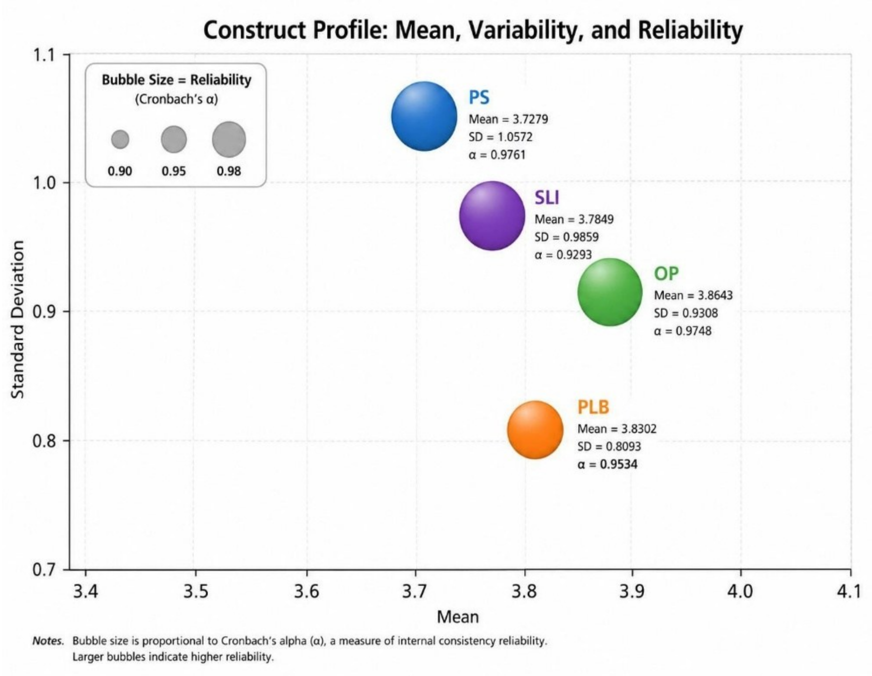

Figure 1. Construct profile: mean, variability, and reliability

Item-Level Results

The item-level results offer more detailed insight into the operational areas that the questionnaire measured. Figure 2 displays the mean scores for the individual items for each of the four dimensions of the questionnaire. The highest item mean for production scheduling was recorded for PS1 (M = 3.89). This means that the respondents generally agreed that production schedules are prepared clearly before production activities take place. PS4 also recorded a high mean (M = 3.87), indicating that the sequencing of production orders contributes to reducing waiting time between production stages. However, PS8 had the lowest mean (M = 3.35) among the production-scheduling items. The result indicates that the factory's response to machine breakdowns, material shortages, or urgent production orders might be relatively weaker compared to other scheduling practices.

For production line balancing, PLB9 recorded the highest mean (M = 4.05), suggesting that respondents perceived workstations as being used effectively during production operations. Strong mean scores (M = 3.89 for each) were also recorded for PLB4 and PLB6, indicating favorable perceptions of corrective measures to lessen bottlenecks and the configuration of the production line to minimize needless waiting. The lowest line-balancing score was recorded for PLB5 (M= 3.65), which relates to keeping idle time at workstations at a low level. This suggests that idle-time reduction remains an important area for operational improvement.

For operational performance, OP8 recorded the highest item mean (M = 4.05), indicating positive perceptions regarding the factory's ability to meet internal or external delivery commitments. OP7 also recorded a high mean (M = 4.01), suggesting that production orders are generally completed within the planned time. The lowest operational-performance score was recorded for OP1 (M = 3.60), which concerns the achievement of a satisfactory level of production output. Although the value remains above the midpoint, it indicates that output performance could still be strengthened.

For scheduling–line balancing integration, SLI1 recorded the highest mean (M = 3.89), suggesting that production schedules are generally prepared in a way that considers the actual balance of the production line. SLI3 recorded the lowest mean (M = 3.68), which indicates that workload distribution adjustments following schedule changes may require further improvement. This result is particularly important because it points to a practical area where the integration between scheduling and line balancing can be strengthened.

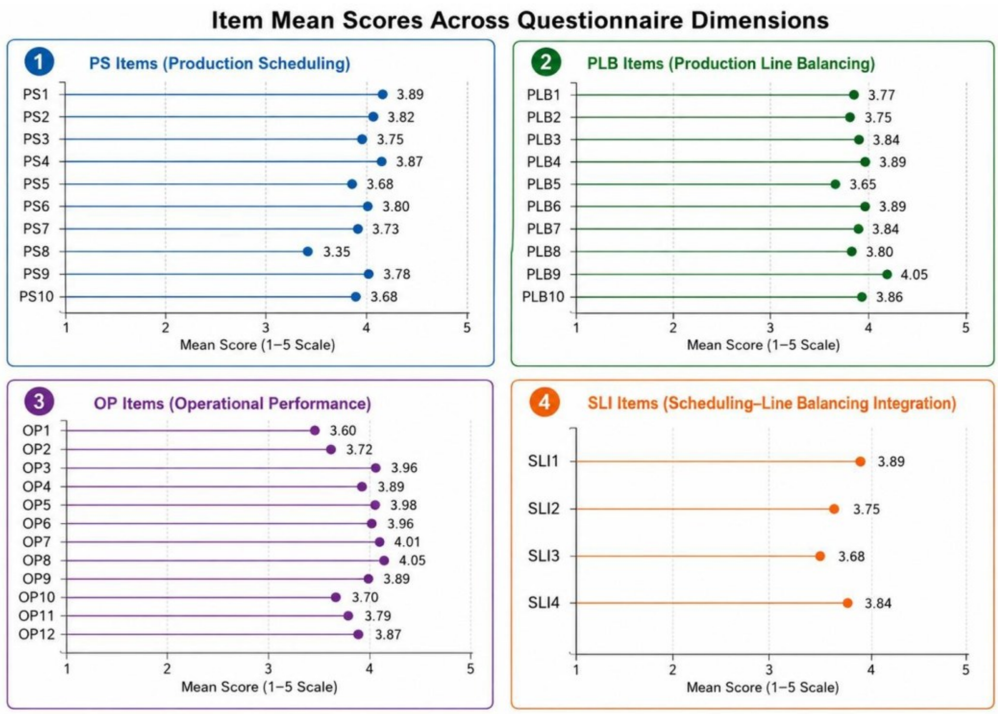

Figure 2. Item mean scores across questionnaire dimensions

Correlation Analysis

As can be seen in Table 3 and Figure 3, all relationships among the main constructs were positive. Production scheduling was positively correlated with operational performance (r = 0.602) showing that better scheduling practices are associated with higher operational performance. Production line balancing was better positively related to operational performance (r = 0.802), indicating that workload distribution, bottleneck reduction, cycle time alignment and workstation utilization are closely linked to operational outcomes.

The claim that production scheduling and production line balancing are related in actual manufacturing settings is supported by the positive correlation between the two practices (r = 0.573). Operational performance and scheduling–line balancing integration had a strong correlation (r = 0.865), meaning that respondents who perceived greater alignment between scheduling and line balancing also reported higher perceived operational performance. Furthermore, the strong correlation (r = 0.901) between scheduling-line balancing integration and production line balancing indicates that effective line balancing provides a central foundation for operational integration within the factory.

The conceptual logic of the study is initially supported empirically by these correlation results. They show that scheduling and balancing are not independent managerial practices but rather are positively related to each other and to operational performance. Nevertheless, causal direction cannot be established by correlation analysis. Regression analysis was therefore used to test the direct and interaction effects proposed in the hypotheses.

Table 3. Pearson correlation matrix of the main variables

Variable	PS	PLB	OP	SLI
Production Scheduling (PS)	1.000	0.573	0.602	0.568
Production Line Balancing (PLB)	0.573	1.000	0.802	0.901
Operational Performance (OP)	0.602	0.802	1.000	0.865
Scheduling–Line Balancing Integration (SLI)	0.568	0.901	0.865	1.000

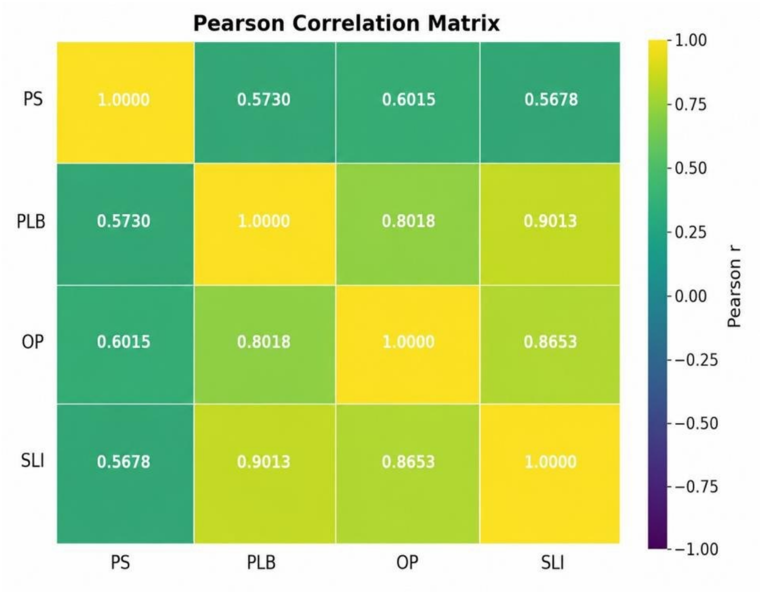

Figure 3. Pearson correlation matrix

Regression Analysis and Hypotheses Testing

Regression analysis was conducted to test the direct and interaction effects proposed in the research model. Table 4 presents the regression results for the main hypotheses. The first regression model examined the effect of production scheduling on operational performance. The results show that production scheduling had a positive and statistically significant effect on operational performance (β = 0.530, t = 4.822, p < 0.001). The model accounted for 36.2% of the variance in operational performance (R^2 = 0.362)). H1 is supported. This result shows that clearer schedules, better sequencing, improved resource allocation, responsiveness to changes, and stronger lead-time control are associated with better operational performance at Samarra Pharmaceutical Factory.

The second regression model tested the effect of production line balancing on operational performance. The results indicate that production line balancing had a positive and statistically significant effect on operational performance (β = 0.922, t = 8.590, p < 0.001). The model explained 64.3% of the variance in operational performance (R^2 = 0.643). Therefore, H2 is supported. This finding indicates that line-balancing practices have a particularly strong role in improving operational performance. In practical terms, better workload distribution, bottleneck reduction, idle-time reduction, cycle-time alignment, and workstation utilization contribute substantially to productivity, efficiency, delivery reliability, cost control, quality stability, and flexibility. The multiple regression model included production scheduling and production line balancing simultaneously as predictors of operational performance. The model explained

67.3% of the variance in operational performance (R^2 = 0.673, adjusted R^2 = 0.657). In this model, production line balancing remained statistically significant (β = 0.783, p < 0.001), while production scheduling was positive but marginally non-significant at the 0.05 level (β = 0.186, p = 0.062). This result suggests that when the two operational practices are considered together, production line balancing captures a large share of the explained variance in operational performance. Nevertheless, the positive coefficient of production scheduling indicates that scheduling still contributes to the model, even though its independent effect becomes weaker after accounting for line balancing.

The moderation model tested whether production line balancing strengthens the relationship between production scheduling and operational performance. The model explained 69.5% of the variance in operational performance (R^2 = 0.695, adjusted R^2 = 0.672). The centered production-scheduling variable was statistically significant (β = 0.215, p = 0.032), and the centered production-line-balancing variable was also significant (β = 0.699, p < 0.001). However, the interaction term was not statistically significant at the 0.05 level (β = −0.160, p = 0.099). Therefore, H3 is not supported statistically at the 0.05 level.

This finding implies that production line balancing accounts for a large share of the explained variance in operational performance when the two operational practices are considered jointly. Even though scheduling's independent effect diminishes when line balancing is considered, the positive coefficient of production scheduling shows that scheduling still contributes to the model.

Table 4. Regression results for hypotheses testing

Model	Predictor	β	SE	t	p-value
H1: PS → OP	Intercept	1.890	0.425	4.445	0.000
	Production Scheduling	0.530	0.110	4.822	0.000
H2: PLB → OP	Intercept	0.332	0.420	0.791	0.433
	Production Line Balancing	0.922	0.107	8.590	0.000
Multiple regression	Intercept	0.172	0.415	0.414	0.681
	Production Scheduling	0.186	0.097	1.917	0.062
	Production Line Balancing	0.783	0.127	6.167	0.000
Moderation model	Intercept	3.941	0.093	42.332	0.000
	PS centered	0.215	0.096	2.230	0.032
	PLB centered	0.699	0.134	5.232	0.000
	Interaction	-0.160	0.095	-1.690	0.099

Table 5. Model Fit Summary

Model	R²	Adjusted R²	F-test p-value
H1 model: PS → OP	0.362	0.346	< 0.001
H2 model: PLB → OP	0.643	0.634	< 0.001
Multiple regression: PS, PLB → OP	0.673	0.657	< 0.001
Moderation model: PS, PLB, Interaction → OP	0.695	0.672	< 0.001

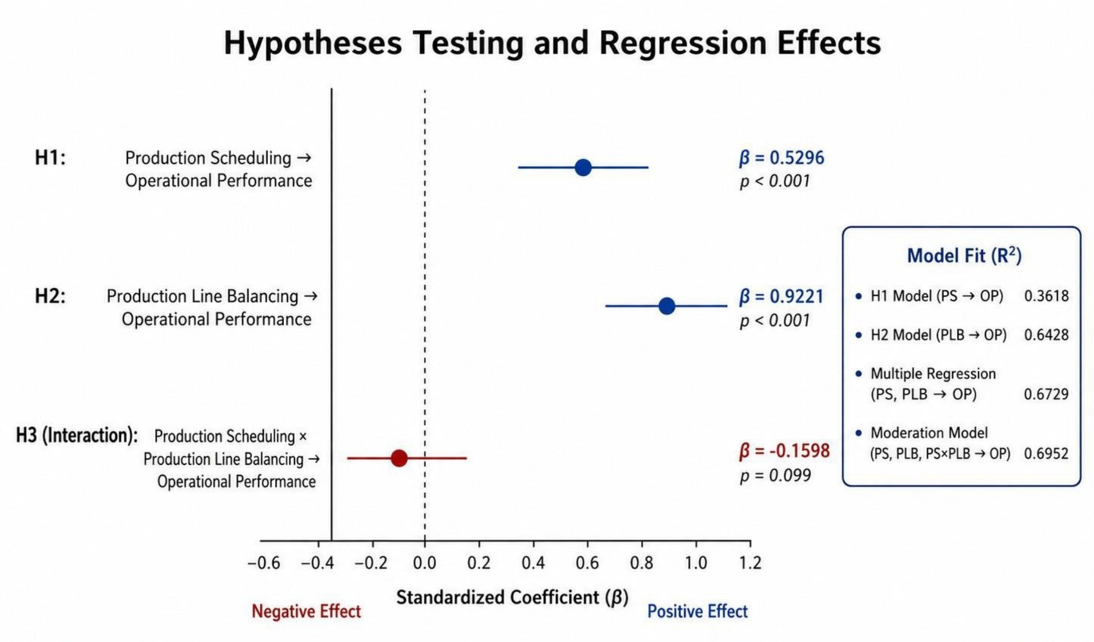

Figure 4. Hypotheses testing and regression effects

Table 6. Summary of Hypotheses Testing

Hypothesis	Statement	Result
H1	Production scheduling has a statistically significant positive effect on operational performance.	Supported
H2	Production line balancing has a statistically significant positive effect on operational performance.	Supported
H3	Production line balancing positively moderates the relationship between production scheduling and operational performance.	Not supported at the 0.05 level

Discussion of Findings

The empirical results offer meaningful evidence of the operational function of line balancing and scheduling in the Samarra Pharmaceutical Factory. The findings demonstrate that production scheduling has a significant positive effect on operational performance, supporting the first main hypothesis. This result supports the operations-management claim that scheduling serves as a coordination mechanism that links resource availability, production orders,machine readiness, material flow, and delivery requirements [5], [7]. The factory can better manage delays, make better use of its resources, and complete production orders within planned time frames when schedules are more precise, responsive, and clear. The factory can better manage delays, make better use of its resources, and complete production orders within planned time frames when schedules are more precise, responsive, and clear.

The second main hypothesis is also strongly supported by the results. Production scheduling had a smaller direct effect on operational performance than production line balancing. Because line imbalance can result in bottlenecks, idle time, cycle-time variation, and congestion between workstations, this is an important finding for the pharmaceutical manufacturing context. Operational performance at Samarra Pharmaceutical Factory is highly sensitive to how well work tasks, stations, employees, and processing times are balanced, as indicated by the strong explanatory power of production line balancing. This outcome is consistent with Boysen et al. [9] and Abdous et al. [10], who highlighted how line-balancing choices support production flow, decrease idle time, and enhance workstation utilization. Additionally, it supports the managerial perspective that line balancing is a strategic operational practice that impacts productivity, efficiency, cost control, delivery reliability, and quality stability rather than just an engineering arrangement of tasks.

However, a more complex interpretation is needed for the moderation result. The interaction term between production scheduling and production line balancing was not significant; hence, H3 was not statistically supported at the 0.05 level. This indicates that there was insufficient statistical evidence in the data to support the idea that production line balancing modifies the degree to which production scheduling and operational performance are related. However, 69.5% of the variance in operational performance was explained by the moderation model, which is substantial in an applied field study. Therefore, the lack of a significant interaction effect should not be interpreted as evidence against the importance of synergy. Instead, it suggests that complementary direct effects and perceived integration—rather than a formal statistical interaction—better capture the synergy in the current sample. The results support the practical complementarity between production scheduling and production line balancing through their positive direct effects and strong association with operational performance, even though the formal moderation effect was not statistically significant. This finding has practical relevance. Both scheduling and line balancing may be essential for improving performance in a pharmaceutical factory, but their effects may operate in parallel rather than in a purely multiplicative form. Line balancing determines whether the production system can smoothly absorb the schedule, while scheduling determines what should happen and when. Operational performance increases when both are present. However, when respondents already perceive that line balancing and integration are relatively high, the marginal effect of scheduling may not necessarily become statistically stronger at higher levels of line balancing.

The item-level results highlight a number of particular areas that require managerial focus. Effectively responding to machine failures, material shortages, or urgent production orders was the weakest aspect of production scheduling. This suggests that one possible area for improvement is rescheduling responsiveness. The reduction of idle time at workstations was the weakest item in production line balancing, indicating that station-level workload and waiting time need to be closely monitored. The weakest component of scheduling–line balancing integration was adjusting workload distribution when schedules change. Because pharmaceutical production frequently deals with changes pertaining to material release, quality-control checks, batch priorities, and equipment readiness, this is an especially crucial point. This interpretation is consistent with Naser et al. [24], who pointed out that bottleneck reduction and cycle time improvement are the main operational issues in pharmaceutical production at Samarra Drug Industry.

Overall, the findings demonstrate that production scheduling and production line balancing enhance operational performance at Samarra Pharmaceutical Factory, providing an answer to the main research question. Because line balancing had a stronger direct effect, managers should focus especially on workstation utilization, cycle-time alignment, and bottleneck reduction. However, scheduling shouldn't be viewed as a distinct administrative task. To ensure that production plans are realistic, adaptable, and aligned with actual production capacity, scheduling should be integrated with line-balancing decisions. Thus, the study reinforces the importance of managing scheduling and line balancing as complementary operational mechanisms within a cohesive framework for performance enhancement.

Conclusions and Recommendations

This study examined the synergistic relationship between production scheduling and production line balancing in enhancing operational performance at Samarra Pharmaceutical Factory. Determining whether scheduling practices, line-balancing practices, and their interaction contribute to improving operational outcomes in a pharmaceutical manufacturing setting was the primary goal. The results demonstrated that all measurement constructs attained excellent reliability based on 43 valid responses, suggesting that the questionnaire items were internally consistent and appropriate for empirical analysis.

The results confirmed that production scheduling has a statistically significant positive effect on operational performance. This implies that better operational results are attained with accurate scheduling, efficient sequencing, adequate resource allocation, responsiveness to change, and lead-time control. Workload distribution, bottleneck reduction, idle-time reduction, cycle-time alignment, and workstation utilization are important drivers of productivity, efficiency, delivery reliability, cost control, and quality stability, according to the findings, which also demonstrated that production line balancing has a stronger positive effect on operational performance. A substantial proportion of the variance in operational performance was explained by the overall model, even though the interaction effect between production scheduling and production line balancing was not statistically significant at the 0.05 level. Thus, the synergistic value of the two practices appears mainly through their complementary direct effects and operational integration rather than through a formal moderation effect.

From a managerial perspective, the study recommends strengthening the coordination between scheduling decisions and line-balancing decisions. Production managers should improve rescheduling responsiveness, particularly when dealing with urgent orders, material shortages, or machine breakdowns. Additionally, the factory should concentrate on reducing idle time at workstations, constantly monitoring bottlenecks, and modifying workload distribution in response to changes in production schedules. To ensure smoother production flow, greater integration between planning, production, quality control, maintenance, and warehousing is needed.

The study has some limitations. It was conducted in one pharmaceutical factory and relied on a relatively modest sample size. It also did not use longitudinal operational records but cross-sectional perceptual data. Future research may extend the model to other pharmaceutical factories, use larger samples, compare public and private manufacturing firms, or combine survey data with actual performance indicators such as throughput, cycle time, delay rates, machine utilization, and defect rates. Future studies may also examine digital scheduling systems, simulation-based line balancing, and lean operations as additional mechanisms for improving pharmaceutical manufacturing performance.

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