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Proposed Improvement of Factory Layout for KSF Industry Sdn Bhd using Flexsim Software

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Abstract

Effective layout planning is crucial for optimizing production efficiency, even when equipment and product design are of high quality. KSF Industry Sdn Bhd, a manufacturer of dried vegetables and fruits, faces challenges due to an irregular facility layout, leading to inefficiencies such as cross-movement from the cutting station to the transfer product station and excessive distances between interconnected stations. This paper aims to propose an improved layout for KSF Industry Sdn Bhd, comparing the time and cost between the current layout and the proposed layout using Flexsim software. A flow process chart was employed to examine the sequence of operations, focusing on material flow movements. Flexsim software was utilized to analyze processor staytime, total output, average content, bottlenecks, processor operation efficiency, and financial data. The current layout's total running time was 1118.05 minutes, whereas the proposed layout's running time was reduced to 1095.02 minutes. Cost analysis for a 1-day process showed a reduction from RM 1,678.80 to RM 1,562.43 in the proposed layout. The percentage improvements in cost and time were 6.93% and 2.6%, respectively. The findings indicate that the proposed layout significantly enhances time and cost efficiency. Consequently, the developed layout is recommended for implementation at KSF Industry Sdn Bhd to optimize their production process.

1. Introduction

The World Economic Forum's Global Competitiveness Index 2017-2018 report placed Indonesia 36th out of 137 countries in terms of industrial competitiveness. This ranking could be enhanced by boosting the productivity of its industries, enabling companies to be more competitive. One effective method to increase productivity in manufacturing companies is through the design of facility layouts. Good equipment and product design may reduce the efficiency if there is messy layout planning. In the advancement of the manufacturing industry, planning and designing factory layouts are important. Companies especially small and medium enterprises (SMEs) ensure that the entire production process, from raw materials to finished products, operates efficiently. An optimal factory layout aims to facilitate the manufacturing process, minimize material handling, conserve space for production, service, and storage planning, and ensure the smooth transfer of materials between operations as quickly, orderly, and safely as possible while keeping costs low.

This paper presents the collaboration project with KSF Industry Sdn Bhd which company that sells dried fruits such as lemon, dragon fruit, durian, lime, and guava. It also has its planting base and uses low-temperature vacuum drying technology. Additionally, KSF Industry Sdn Bhd specializes in producing dried fruits and vegetables with original flavors. It uses the fruits and vegetables planted on its own and contract farms to process, thereby avoiding high rejection rates or wastage.

In this paper, computer-aided modeling software is employed to monitor the advancement of facility layout. One approach to assessing the enhancement of facility layout involves computer-aided simulation, with FlexSim software utilized for this purpose. FlexSim Simulation Software helps in designing factory layouts. It lets users create a 3D model of the production process and test different setups. By using real data, people can see how materials move, how workstations are used, and how well the layout works overall. FlexSim compares different layouts, showing the pros and cons of each. It provides detailed measurements, visualizations, and reports to help make informed decisions, ensuring the chosen layout is optimized and ready for implementation. In short, FlexSim enhances the efficiency and effectiveness of manufacturing operations through comprehensive, informed analysis. Therefore, this paper presents the proposed improvement layout for KSF Industry Sdn Bhd's production facilities with the help of simulation by Flexsim Software.

2. Literature Review

2.1 Facilities Layout

Facility layout is crucial for operational efficiency, affecting the speed and quality of work across industries (Slack et al., 2019). Scholars have studied various strategies, such as cellular manufacturing, which groups similar processes to enhance workflow and reduce material handling, thereby improving system performance and reducing lead times (Heragu, 2006; Karimi et al., 2012). Advanced technologies like simulation and optimization tools model dynamic facility behaviors and identify efficient resource arrangements (Rosset et al., 2017). Human-centric design principles, focusing on ergonomics, enhance worker satisfaction and reduce injury risks (Mital et al., 2011). Common layout types include process layouts, which group similar functions for production flexibility; product layouts, which use sequential workstations to streamline high-volume production (Buffa & Sarin, 2007); and cellular layouts, which foster teamwork and communication, particularly in lean manufacturing (Hopp & Spearman, 2000). Fixed-position layouts are used for large, immovable products, minimizing material handling needs (Russell & Taylor, 2014). Hybrid layouts combine elements from different types to address specific industry challenges (Niebel et al., 2003). In food manufacturing, such as vegetable and fruit drying, the layout must facilitate smooth cross-movement and maintain hygiene, with cellular and fixed-position layouts optimizing time and minimizing damage during tray-to-tray processes (Brown, 2021). Overall, a well-designed facility layout enhances operational efficiency, worker well-being, and job satisfaction (Mueller, 2005).

2.2 Previous research work on layout improvement

The history of layout improvement research highlights the evolution of design, and the efficiency gains achieved using software like Flexsim, Mathematical Programming, WITNESS, and ARENA. Reviewing previous studies helps identify improvements made previously, especially in time, cost, and efficiency, hence guiding the selection of appropriate layouts for projects like those at KSF Industry Sdn Bhd. Table 1 summarizes previous research work related to layout improvement using different software.

Table 1 Previous research work-related

No.	Author	Study	Method	Finding	
				Cost	Time
1	Patil (2019)	optimization of machine shop layout (eliminated dispatcher and modified arrangement of various machines)	Simulate: Flexsim Software	N/A	N/A
2	Smaili (2020)	utilization of Flexsim software to identify the suitable layout planning of the production line	Simulate: Flexsim Software	N/A	N/A
3	Kumar (2015)	productivity improvement in a Windows manufacturing layout using Flexsim simulation software	- AutoCAD software	X	/
4	Chen	optimizing production layout and capacity via Flexsim	Simulate: Flexsim	X	/

	(2020)	– a case study of y factory	Software		
5	Karim (2022)	facility layout improvement for Erul food industry: a simulation and comparison	- Sketchup - Simulate: Flexsim Software	/	/
6	Suriansah (2022)	a simulation of facility layout improvement at a local food industry	- Sketchup Flexsim - Simulate: Flexsim Software	/	/
7	Kovacs (2017)	facility layout redesign for efficiency improvement and cost reduction	Analysis: Mathematical Programming	N/A	X
8	Ojaghi (2015)	production layout optimization for small and medium-scale food industry	Simulate: MATLAB Software (Mathematical Programming)	N/A	N/A
9	Hussin (2019)	redesign of bahulu production layout to improve the efficiency of process flow	Simulate: WITNESS software	X	/
10	Ahmad (2018)	the effectiveness of the conveyor layout affected the production output using arena simulation software	Simulate: ARENA Simulation Software	N/A	N/A
11	Gozali (2022)	raw material warehouse layout design using class-based storage method with pro model and flexsim simulation at automotive assembling company	Simulate: Flexsim Software	/	/
13	Naranjo *et al.* (2023).	facility layout proposal for a tannery, evaluated by the simulation software-flexsim	Simulate: Flexsim Software	/	/
14	Zakka *et al.* (2019)	evaluation of redesign layout using discrete event simulation (des)	Simulate: Flexsim Software	/	/
15	Satyajeet *et al.* (2019)	optimization of machining facility layout by using simulation: a case study	Simulate: Flexsim Software	/	/
16	Kumkum *et al.* (2018)	systematic efficiency improvement by optimizing the assembly line using witness simulation	Simulate: Witness Software	X	/
17	Jaffrey (2017)	improvement of productivity in low-volume production industry layout by using witness simulation software	Simulate: Witness Software	X	/
18	Zulkipli *et al.* (2019)	optimization of machine shop layout using Flexsim software	Simulate: Flexsim Software	/	/
19	Smaili *et al.* (2021).	utilization of Flexsim software to identify the suitable layout planning of the production line	Simulate: Flexsim Software	N/A	N/A
20	Suhardi *et al.* (2019).	facility layout improvement in the sewing department with systematic layout planning and ergonomics	Simulate: Arena Software	/	/

		approach			
21	Mohd *et al.* (2013)	improvement of production line layout using arena simulation software. applied mechanics and materials	Simulate: Arena Software	/	/

Research into layout improvement techniques has yielded significant findings across various studies. Patil (2019) demonstrated a substantial increase in productivity with a new layout iteration, while Fidan (2020) achieved a 64.7% boost in production capacity through redesign. Kumar (2015) and Chen (2020) highlighted improvements in output and efficiency metrics, including reduced travel distances and times. Karim (2022) and Suriansah (2022) both identified efficiency gains and cost reductions with new layout designs. Other studies, such as those by Kovcas (2017), Ojaghi (2015), and Hussin (2019), reported enhanced efficiency rates and reduced processing times. Gozali (2022) and Kovács (2019) emphasized significant cost savings and efficiency improvements through optimized layouts. Simulation software, as evidenced by studies from Suhardi *et al.* (2019), Azrin (2013), Kumkum *et al.* (2018), and Jaffrey *et al.* (2017), proved effective in reducing material handling costs, improving production line layouts, and enhancing overall productivity and efficiency.

2.3 Flexsim Software

Flexsim is a widely utilized discrete event simulation software known for optimizing processes and improving efficiency across various industries. In healthcare, studies by Smith *et al.* (2018) and Brown *et al.* (2019) illustrate its ability to streamline patient flow and enhance emergency department layouts, respectively, improving operational performance and patient care. In manufacturing and supply chain management, research by Jones *et al.* (2020), Wang *et al.* (2019), and Garcia *et al.* (2020) demonstrate how Flexsim optimizes supply chain processes, reduces lead times, and lowers costs through simulation-driven decision-making. Flexsim's versatility and impact extend to logistics, as shown by Kim *et al.* (2021) study on warehouse layout design, highlighting its role in improving operational efficiency and resource allocation.

2.4 Flexsim simulation of time and cost

Simulation involves replicating real-world processes or systems in a controlled virtual environment to study and improve their efficiency and productivity. According to Banks *et al.* (2005), simulations create models that mimic essential characteristics of real processes, allowing researchers and practitioners in fields like engineering, healthcare, and business to analyze scenarios and optimize decision-making. Studies by Pressman *et al.* (2014) and Altiok *et al.* (2007) highlight how well-designed software, such as simulation tools, can streamline operations, automate tasks, and optimize resources. Challenges like data accuracy and model validation remain important for ensuring simulations accurately reflect real-world conditions, crucial for reliable decision support. In food production, simulation studies by Smith *et al.* (2018) and Chen *et al.* (2019) demonstrate how simulation modeling reduces bottlenecks, optimizes layouts, and enhances operational efficiency by minimizing process time and improving productivity.

Previous studies indicate that a majority of researchers, approximately 61.90%, prefer using FlexSim software for improving layouts, with a strong emphasis, 92.31%, on enhancing production efficiency by reducing production cost and time. This preference underscores the software's effectiveness in addressing common factory challenges like bottlenecks, cross-movement, and production capacity issues. FlexSim is valued for its user-friendly interface, 3D visualization capabilities, and flexibility in modeling complex systems, making it ideal for intuitive layout analysis. In contrast, ARENA and WITNESS software are recognized for their optimization capabilities and efficiency in handling large and intricate models, often through mathematical programming. However, these methods may be more resource-intensive and less visually intuitive compared to FlexSim's simulation approach, which offers quicker insights and requires less effort in certain contexts. This flexibility makes FlexSim suitable for achieving objectives and solving layout-related problems at factories like KSF Industry Sdn Bhd. The chapter also discusses the integration of SketchUp for initial design and subsequent simulation using FlexSim, highlighting the software's role in enhancing layout design through simulation methodologies.

3. Methodology

The methodology or steps is to conduct the project to achieve the objective of this project, which consists of Flexsim software to simulate and analyze the proposed layout. The flow of methodology is expressed by using a flowchart. All the content in the method is a step-by-step procedure in the Proposed Layout for KSF Industry Sdn. Bhd. Figure 1 shows a flowchart of the methodology in this paper.

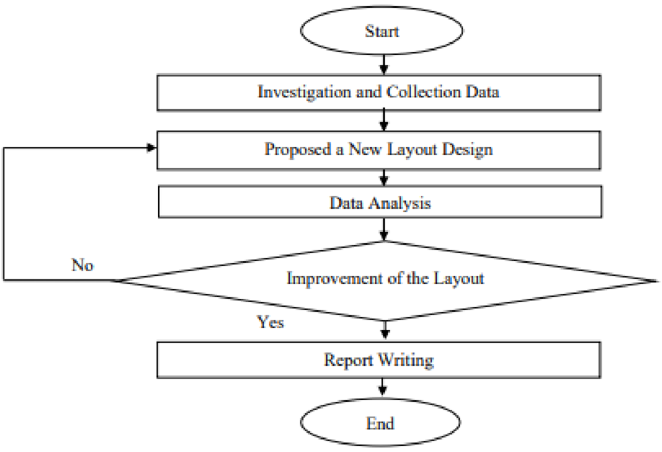

Fig. 1 Flowchart of Methodology

3.1 Data Collection for The Current Layout

A site visit to KSF Industry Sdn Bhd was conducted to identify layout-related issues through observation and interviews. During layout observation, it was observed that inefficient trolleys might cause delays in material movement, particularly in the transition from trolleys to tray dryers, compounded by significant cross-movement and long distances between stations. This led to higher handling costs and extended production times, highlighting the need for a redesign to streamline material flow. The production process, starting with raw materials like lemon, guava, dragon fruit, and pineapple, faced bottlenecks, especially in transferring cut lemons to the tray dryer, further hampered by a single entry and exit path for workers. The lemon-drying process, involving machine drying and multiple trolley movements, posed hygiene concerns due to prolonged waiting times. Addressing these logistical challenges is crucial for maximizing efficiency and productivity. The facility uses a process layout, arranging equipment and workstations by production sequence, offering flexibility for different products. The interview session provided insights into the company's operations, including their dual approach to fruit drying using machines and solar methods, enhancing the understanding of their production processes.

For this case study, it is assumed that the costing analysis is based on standardized cost parameters and hypothetical data to allow for effective comparison and evaluation. These assumptions are made to facilitate a clearer understanding of the cost implications associated with the current layout and the proposed redesign. It should be noted that actual costs may vary due to fluctuations in material prices, labor rates, and other operational factors specific to KSF Industry Sdn Bhd. This standardized approach ensures consistency in analysis and provides a foundational basis for assessing potential improvements in the production process.

3.2 Development of Proposed Layout

Layout design development involves refining an initial concept into a detailed plan by examining the existing layout, identifying improvement areas, and implementing effective changes. The goal is to enhance efficiency, and productivity, and meet organizational needs by strategically placing equipment, optimizing movement, ensuring accessibility, and adhering to standards. This process tailors the layout to the specific workstation needs of KSF Industry Sdn Bhd, with SketchUp software used for sketching and designing purposes.

3.3 Sketchup Software Application

Using realistic 3D views is essential for clear design descriptions, as it allows for better visualization of objects and spaces compared to limited 2D drawings. 3D visualization aids in identifying potential problems, improving design accuracy, and facilitating clear communication among stakeholders. SketchUp software is a powerful tool for creating and viewing 3D models quickly. Its user-friendly interface is suitable for both professionals and beginners, featuring simple tools for drawing and modifying 3D objects. The extensive library of ready-made models in SketchUp's 3D Warehouse saves time and effort, and its compatibility with other design and rendering software ensures a smooth workflow, making it a versatile choice for various projects.

3.4 Simulation of Proposed Layout

Simulation enables companies to optimize layouts, enhance efficiency, reduce production time, and achieve significant cost savings by modeling physical systems digitally. By assessing material movement within layouts, identifying bottlenecks, and optimizing flow paths, simulations improve material flow and space utilization, leading to faster production cycles (Katiyar, 2017). For instance, Yeole (2008) used simulation to enhance the layout of a Windows manufacturing facility, resulting in faster production and reduced lead times. Similarly, *Khan et al.* (2020) study on a garment manufacturing facility demonstrated a 15% reduction in operator requirements and annual savings of over $100,000 through layout optimization and automation. FlexSim software, a 3D factory simulation program, helps in addressing real-world manufacturing issues and optimizing designs. Furthermore, layout optimization significantly impacts time and cost, as evidenced by *Niebel et al.* (2009), who found that appropriate layouts decrease travel distances and time expenses. Tompkins (2016) highlighted the link between layout configuration and production cycle time, while Malakooti (2013) showed that better layouts increase productivity and lower labor costs. Additionally, Muther (1973) and Francis and White (1974) emphasized the role of proper layouts in optimizing space usage and minimizing inventory costs. Thus, simulation is vital for achieving high-quality layout designs, such as for KSF Industry Sdn Bhd, by identifying problems and preventing costly construction errors and workflow inefficiencies.

4. Results and Discussion

Data analysis from the current layout is data of the simulation's current layout design. This simulation is set up by referring to the current layout at KSF Industry Sdn Bhd. The arrangement of the station is the same as which has been constructed. Figure 2 and Figure 3 show the interface simulation and data of the current layout design while Figure 4 and Figure 5 show the interface simulation and data of the proposed layout design.

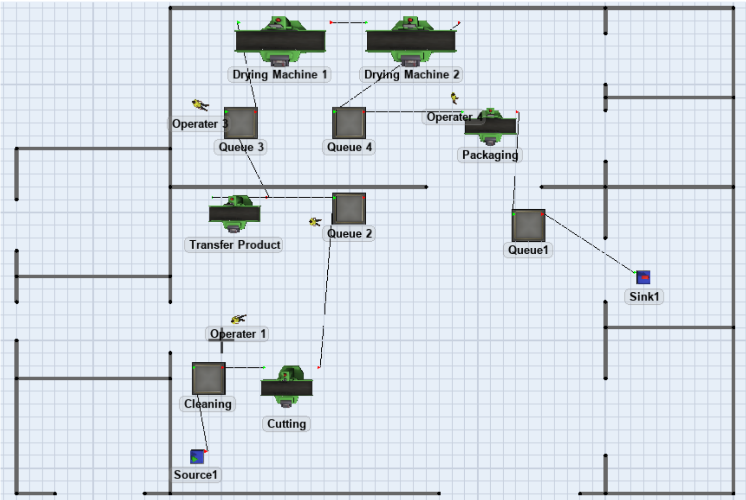

Fig. 2 Simulation of the current layout

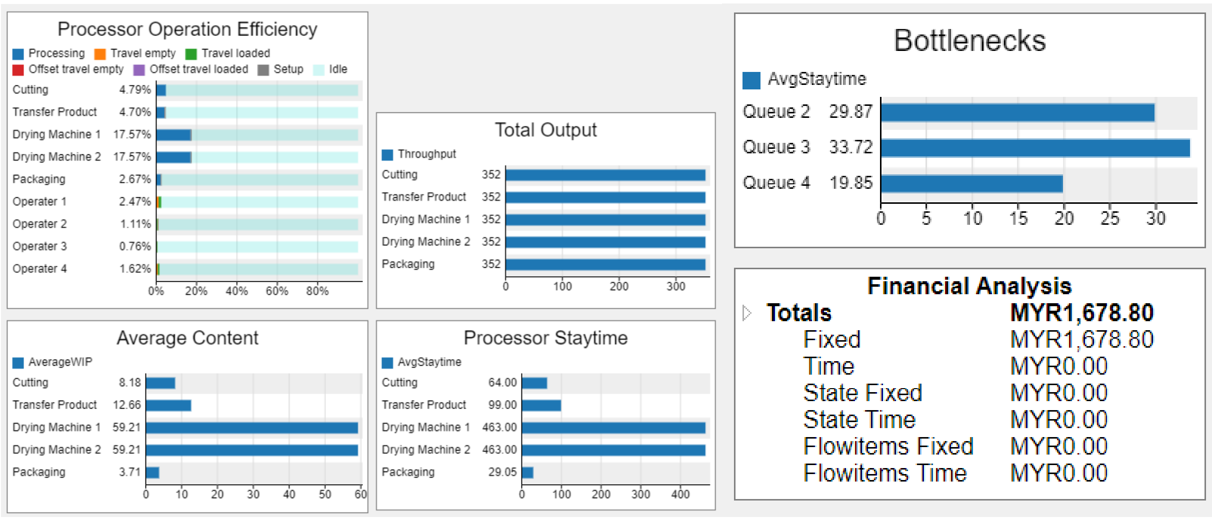

Fig. 3 Data of the simulation's current layout

Figure 3 presents the throughput for the current layout simulation, producing 352 items at each stage—Cutting, Transfer Product, Drying Machine 1, Drying Machine 2, and Packaging—all demonstrating a balanced production flow. The average Work in Progress (WIP) is highest in Drying Machines 1 and 2 at 59.21 units, followed by Transfer Product at 12.66 units, indicating these as potential bottlenecks. Cutting and Packaging show lower WIP at 8.18 and 3.71 units, respectively. Processor staytime and operation efficiency are detailed as follows: Cutting - 64 minutes, 4.79%; Transfer Product - 99 minutes, 4.70%; Drying Machines 1 and 2 - 463 minutes, 17.57%; Packaging - 29.05 minutes, 2.67%. The simulation highlights that all stations reached 47.3% efficiency. Operator efficiencies are reported as Operator 1: 2.47%, Operator 2: 1.11%, Operator 3: 0.76%, and Operator 4: 1.62%. Significant delays are noted in Queue 2 (33.72 minutes), Queue 1 (29.87 minutes), and Queue 3 (19.85 minutes), indicating these as bottlenecks. The financial analysis shows the overall cost for a 1-day process is RM1678.80, with a total run time of 1118.05 minutes.

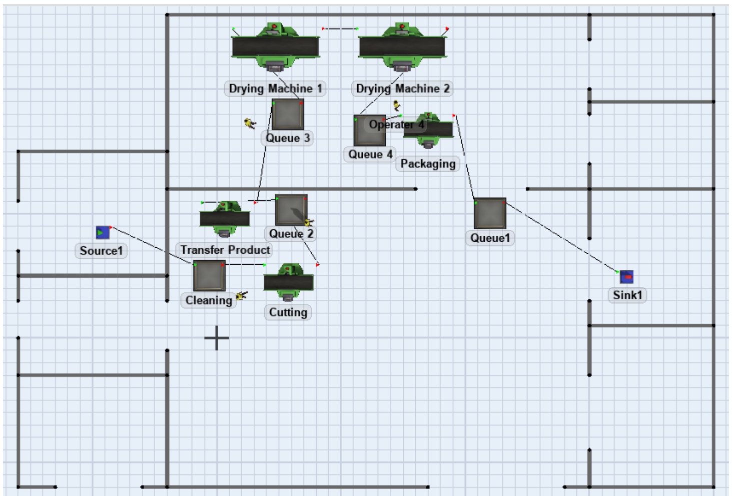

Fig. 4 Simulation of the proposed layout

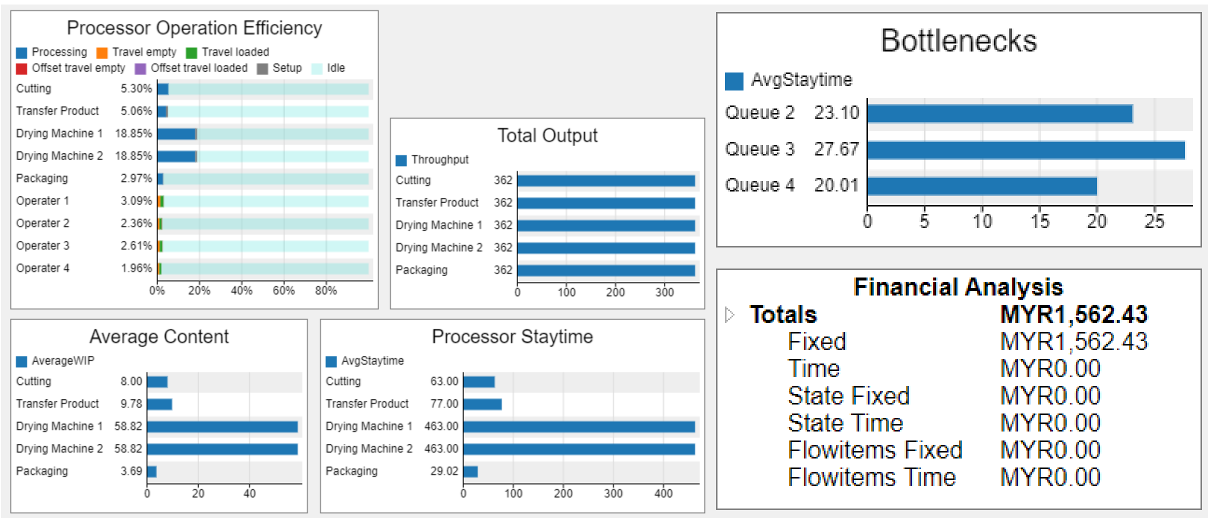

Fig 5 Data of the simulation's proposed layout

Figure 5 presents the throughput for the proposed layout simulation, producing 362 items at each stage—Cutting, Transfer Product, Drying Machine 1, Drying Machine 2, and Packaging—indicating a balanced production flow. The average Work in Progress (WIP) is highest in Drying Machines 1 and 2 at 58.82 units, followed by Transfer Product at 9.78 units, highlighting potential bottlenecks. Cutting and Packaging show lower WIP at 8 and 3.69 units, respectively. Processor staytime and operation efficiency are detailed as follows: Cutting - 63 minutes, 5.30%; Transfer Product - 77 minutes, 5.06%; Drying Machines 1 and 2 - 463 minutes, 18.85%; Packaging - 29.02 minutes, 2.97%. The simulation shows all stations reached 51.03% efficiency. Operator efficiencies are reported as Operator 1: 3.09%, Operator 2: 2.36%, Operator 3: 2.61%, and Operator 4: 1.96%. Significant delays are noted in Queue 3 (27.67 minutes), Queue 2 (23.1 minutes), and Queue 4 (20.01 minutes), identifying them as bottlenecks. The financial analysis indicates the overall cost for a 1-day process is RM1562.43, with a total run time of 1095.02 minutes. Table 2 shows the comparison of data of time and cost analysis between the current layout and the proposed layout.

Table 2 Comparison of data between time and cost analysis

No.	Design	Dashboard	Current Layout	Proposed Layout

1	Time	Processor Staytime (min)	1118.05	1095.02
2	Cost	Financial Analysis (RM)	1,678.80	1562.43

The simulation shows that the proposed layout has a shorter total running time (1095.02 minutes) compared to the current layout (1118.05 minutes), despite bottlenecks. The difference in processor time between the layouts is minimal, suggesting the overall production process duration is comparable. However, the proposed layout incurs a lower cost for a 1-day process at RM1562.43, compared to RM1678.80 for the current layout. The cost analysis indicates that the cost per station, based on state time, is RM1.50, reflecting the overall cost of all processors during product flow. This financial estimate is influenced by the station manufacturing line and the product completion time. Thus, a shorter manufacturing running time correlates with lower production costs, making the proposed layout more efficient and cost-effective for KSF Industry Sdn Bhd.

5. Conclusion

The facility layout design for KSF Industry Sdn Bhd was developed using SketchUp software to meet production needs effectively, focusing on worker movement, distances, and space utilization. Layout designs were simulated using FlexSim software for comparison with the current layout. The simulation showed potential reductions in both production time and costs for the proposed layout. Specifically, the proposed layout reduced production time from 1118.05 to 1095.02 minutes and lowered costs from RM 1,678.80 to RM 1562.43. Key changes included repositioning cleaning and cutting stations to optimize product transfer and relocating raw material stations. Overall, the proposed layout design demonstrated a 2.6% reduction in time and a 6.93% decrease in costs, proving more efficient than the current layout and enhancing productivity at KSF Industry Sdn Bhd.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Nur Fatin Farzana Nooranizam, Salwa Mahmood;* ***data collection:*** *Nur Fatin Farzana Nooranizam;* ***analysis and interpretation of results:*** *Nur Fatin Farzana Nooranizam, Salwa Mahmood, Danial;* ***draft manuscript preparation:*** *Nur Fatin Farzana Nooranizam, Salwa Mahmood. All authors reviewed the results and approved the final version of the manuscript.*

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