ENHANCING FACILITY LAYOUT PLANNING (FLP) EFFICIENCY THROUGH SIMULATION

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ABSTRACT: Facility layout planning (FLP) which involves organizing production process components within a physical space, presents unique design challenges. This study addressed inefficient FLP at Workshop S, an automobile repair workshop, due to poor space utilization and reduced operational efficiency. This study also proposed an optimum layout to improve operation time and cost-efficiency. Conducted in Pekan Pagoh, Johor, this study employed a combination of layout design and simulation methodology. Two new layouts (Design 1 and Design 2) were evaluated against the current layout. The analysis showed that Design 2 reduced the average operation time per car by 19% (from 117.35 to 95 minutes) and daily cost by 17.7% (from RM1504.36 to RM1237.72). Therefore, Design 2 was recommended for Workshop S. These findings are expected to significantly enhance operational efficiency and cost-effectiveness at their workstations, serving as a model for similar workshops facing layout inefficiencies.

KEYWORDS: *Facility layout planning, layout improvement; FlexSim software*

1.0 INTRODUCTION

Facility layout planning (FLP) is the process of structuring all the production variables that constitute the production system to efficiently meet strategic business objectives. FLP stands as one of the most critical design considerations in terms of company operating strategies [1][2][3]. Moreover, it significantly influences the quality and efficiency of industrial automation [4][5][6]. An effective FLP ensures that schedules are adhered to in the short, medium, and long term, while reducing costs and using space optimally. This facilitates flexibility for future re-layouts and minimizes health and safety risks at the workplace. Conversely, inefficient FLP can lead to bottlenecks, congestion, and underutilized space, resulting in excessive work in progress while job listings become inactive or overburdened. This may also cause uneasiness and dissatisfaction to employees, as well as workplace mishaps, complicating operations and people management [7]. The position of work equipment within the plant significantly impacts production efficiency and also improves throughputs [8].

With the advent of Industry 4.0, FLP simulation has become a critical tool for the modern workshops. Advanced simulation software allows virtual testing and optimization of layouts prior to physical implementation, identifying potential inefficiencies and mitigating risks. By employing simulation tools, businesses can dynamically model and visualize different layout scenarios, ensuring the most efficient arrangement of resources and workflow processes. This trend in FLP simulation not only enhances productivity but also supports continuous improvement and agility in adapting to changing operational demands.

Despite the growing use of FLP simulation in large-scale manufacturing and production systems, its application in small and medium-sized enterprises (SMEs), particularly in the automobile repair and service sector, remains limited. Existing studies often emphasize high-volume manufacturing settings, leaving a gap in research on how simulation-based FLP can address inefficiencies in small workshops where space constraints and process bottlenecks are common. Furthermore, there is insufficient empirical evidence on quantifying the improvements in operational time and cost when applying simulation-driven layout planning in such contexts.

The primary objective of this research was to address the inefficiencies in FLP by proposing and simulating several layout designs to identify the most suitable layout in terms of operation time per car and daily operation cost. Workshop S, an automobile repair and services workshop located in the Pagoh area, was chosen as the case study. The inefficiency of the current layout results in excessive time and effort spent maneuvering vehicles and accessing tools and equipment, leading to bottlenecks and delays in the repair process. This situation not only limits the number of cars that can be serviced daily but also increases operation costs due to prolonged service times and underutilized workspace. Suboptimal layout hampers the workshop's ability to meet customer demand efficiently and affects overall productivity and profitability. The proposed layout design from this research can significantly improve the efficiency and profitability of the operation.

2.0 METHODOLOGY

FLP involves the structuring of all production variables within the production system to efficiently meet strategic business objectives. In this study, FLP was applied to Workshop S, focusing on its specialized overhauling service. Observation was made to understand the current processes and layouts used. Relevant data were recorded during the observation, and interviews were conducted with the workers.

The top overhauling service at Workshop S began with parking the car in the designated area and then removing the engine. The engine was taken to the disassembly table to remove the faulty parts. These parts were then transferred to the cleaning to ensure they were free from dirt or impurities. Subsequently, any broken parts were repaired or replaced at the next table, ensuring a clean and organized process. After all repairs were completed, the engine components were reassembled, and the engine was re-installed back into the car. Finally, the engine was subjected to testing to ensure proper functionality. The general flow of the overhauling service is illustrated in Figure 1.

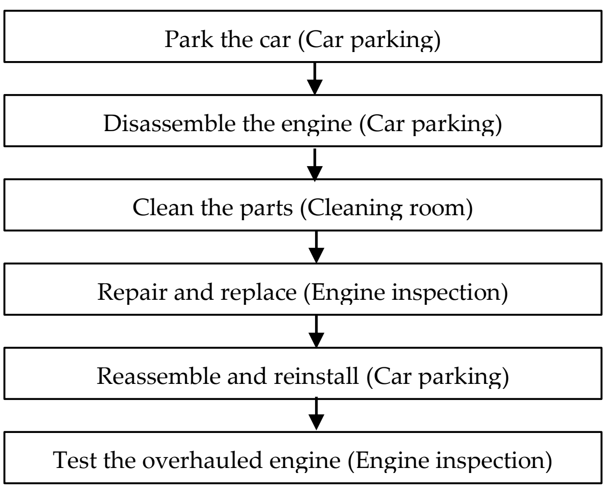


Figure 1: Overhauling processes

Using the information obtained during the observation, the current layout of Workshop S was drawn. Adjustments were then made to the original layout through FLP. These adjustments resulted in two proposed layouts for Workshop S, namely Design 1 and Design 2.

This research was also supported by two software tools: i) SketchUp Software to create a simple 3D model of the layouts, and ii) FlexSim Software to conduct comparative analysis of operation time and cost.

2.1 SketchUp Software

SketchUp Pro 2022 is a three-dimensional modeling tool that allows users to create, display, and communicate ideas. It consists of a three-dimensional visual display that can be used to generate anything from simple 3D forms to complex models, encouraging creativity [9].

SketchUp Pro 2022 offers a high-functioning environment with a low entry point and high ceiling, enabling the creation of advanced models that surpass traditional foam-core models. Its camera features allow users to walk through digital model at eye level.

The following are steps to utilize SketchUp Pro 2022:

i. Open SketchUp software to display the drawing template with specific dimensions.
ii. After the template is selected, a blank template will show all the 3D drawing tools.
iii. Design the layout according to the specified dimensions.
iv. Label all the objects that have been drawn in the layout.
v. Save the layout as a PNG file to include in the research results.

2.2 FlexSim Software

FlexSim is a software platform used for developing, modeling, simulating, visualizing, and monitoring dynamic-flow process activities and systems. FlexSim software includes a comprehensive set of development tools for creating and compiling simulation programs [10]. It is also used to construct simulation software models for various applications, aligning with the current trend of Industry 4.0, which drives firms towards automation and enhanced communication [11].

Organizations and corporations utilize FlexSim software to increase income, reduce costs, eliminate waste, and optimize business processes [12].

FlexSim has been used in various simulation projects for both traditional and flexible production systems in manufacturing. For over a decade, it has supported automating the creation of simulation models and interfaced with Product Lifecycle Management (PLM) software [13]. It can also be enhanced with C++ for real-time data transfer and near-real-time production planning, offering improvements over traditional methods [14]. It is also used to optimize the plant's production capacity [15].

3.0 RESULTS AND DISCUSSION

This section presents the FLP simulation results of the proposed facility layouts and their implications for Workshop S. To assess the improvements in operational efficiency, specifically operation time per car and daily operation cost, the current layout was compared with the proposed Design 1 and Design 2. The discussion presented in this section explores the alignment of these findings align with the research objectives, identifies potential areas for further improvement, and provides insights into the practical applications of the optimized layouts.

3.1 Construction of Layouts using SketchUp Software

Figure 2 illustrates the current layout of Workshop S, which was constructed based on observations. The dimensions of this workshop were 10 meters in width and 24 meters in length. The current arrangement of tools and machines was improper, as evidenced by interviews with workers. They claimed that the existing layout decelerated the repair process due to the great distance between stations. As indicated by the overhauling processes in Figure 1, the material movement is as follows: car parking-cleaning room-engine inspection-car parking-engine inspection.

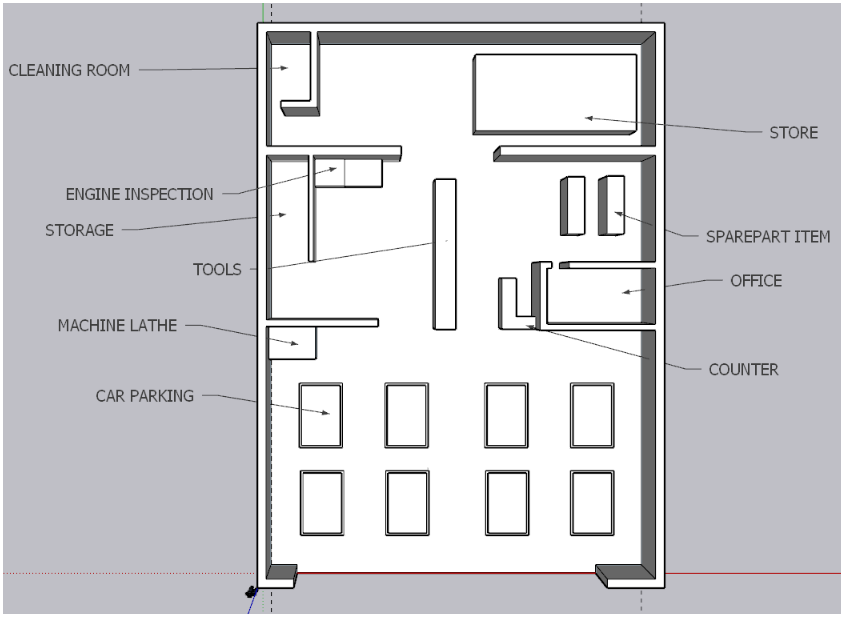


Figure 2: Current layout of Workshop S

Therefore, Design 1 and Design 2 layouts were proposed, which offered several improved layout characteristics, such as higher utilization of space, equipment and people; and improved flow of information, materials and people [16]. Design 1, as displayed in Figure 3, presented a reorganization of the sections, with the cleaning section moved to the front area. Given that the cleaning section is used more frequently than the storage section, this interchange could reduce movement and distance, thereby decreasing operation time.

On the other hand, Design 2, as shown in Figure 4, was an enhanced version of Design 1. It featured a restructured front layout of the workshop, including car parking area and processor. This redesign aimed to create additional space in the repair department and facilitate a more efficient workflow for mechanics.

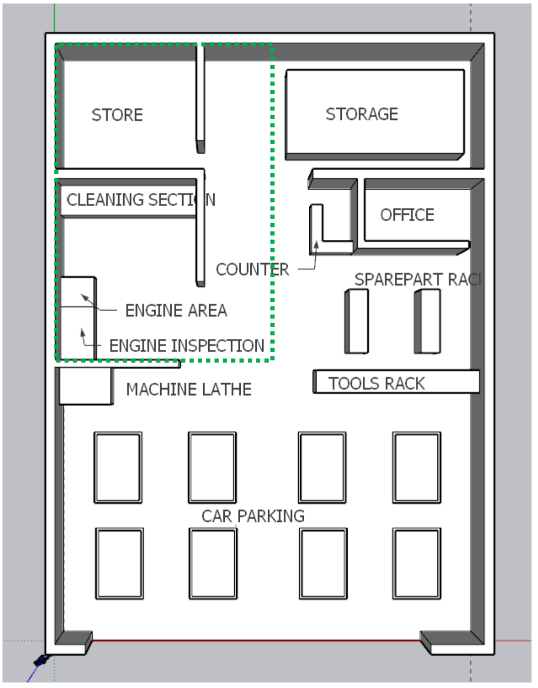


Figure 3: Proposed layout - Design 1

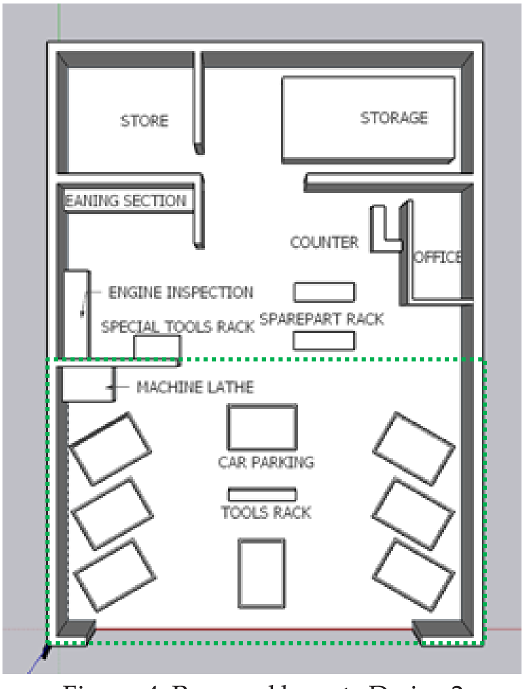


Figure 4: Proposed layout - Design 2

3.2 Simulation Using FlexSim Software

In the FlexSim software, the data required for the simulation was the operation time, while the arrows connecting the sections (icons created in the FlexSim workspace) represented the overhauling process flow. In this research, the operation time was set at 600 minutes, corresponding to the workshop operation hours from 9 am to 7 pm. This setup accurately reflected the daily operation timeframe of Workshop S, allowing the simulation to realistically model the flow of activities. The arrows between sections illustrated the sequence of processes, ensuring the simulation captured the interactions and dependencies between different workstations. By accurately entering these parameters as input, the simulation could provide reliable data regarding the efficiency and effectiveness of the proposed layouts. Upon simulation, several data were obtained, namely process stay time, financial analysis, number of cars finish and processor operation.

Figure 5 illustrates the FlexSim setup of the current layout. From the simulation (Figure 6), it revealed an average operation time of 117.35 minutes per car. Using the current layout, Workshop S was able to overhaul 10 cars per day, as indicated in Figure 7. In Figure 8, smooth operation was demonstrated for the tasks of installing/uninstalling engines, assembly/disassembly, and repairing. However, cleaning operation experienced 8%-time blockage, decelerating the overhauling process due to collisions. Finally, Figure 9 shows the total cost for the one-day operation of Workshop S with the current layout, which was RM1504.36, comprising a fixed cost of RM700 and process time cost of RM804.36. The obtained data were used as a baseline or reference to determine the effect of layout changes in the proposed layouts, namely Design 1 and Design 2, on operation time and cost.

Subsequently, the proposed layouts of Design 1 and Design 2 were simulated using the same software, Figures 10 until 13 display the results obtained, while Table 1 shows the parameter differences between the current layout, Design 1 and Design 2.

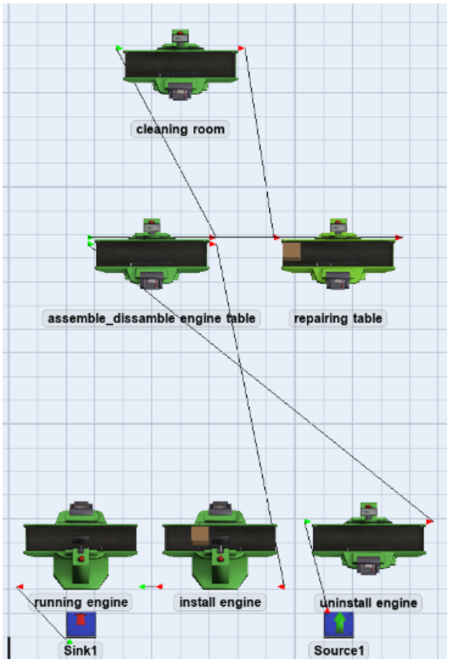


Figure 5: FlexSim setup for current layout

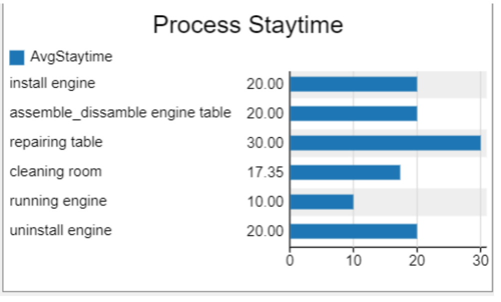


Figure 6: Operation time of current layout

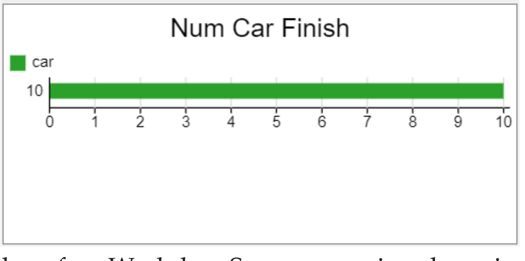


Figure 7: Number of car Workshop S can process in a day using current layout

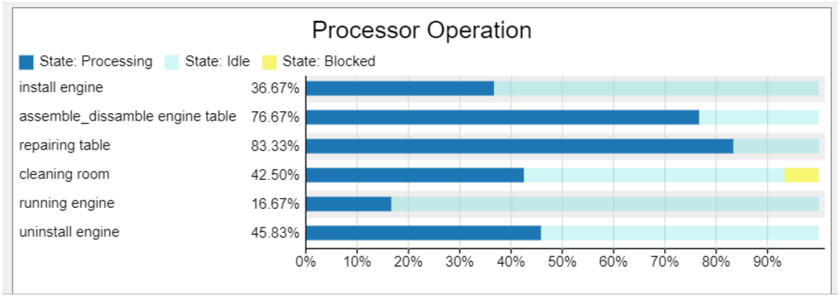


Figure 8: Operation state of current layout

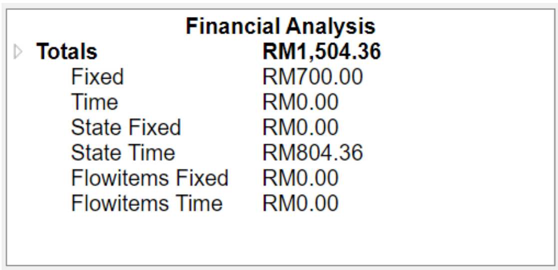
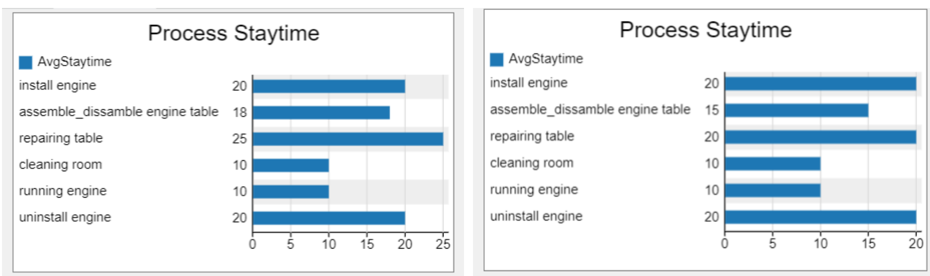
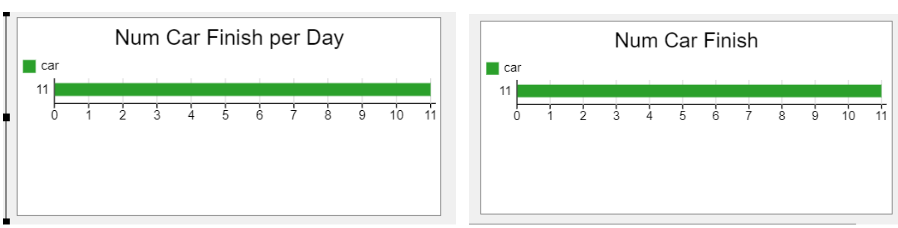


Figure 9: Financial analysis of current layout



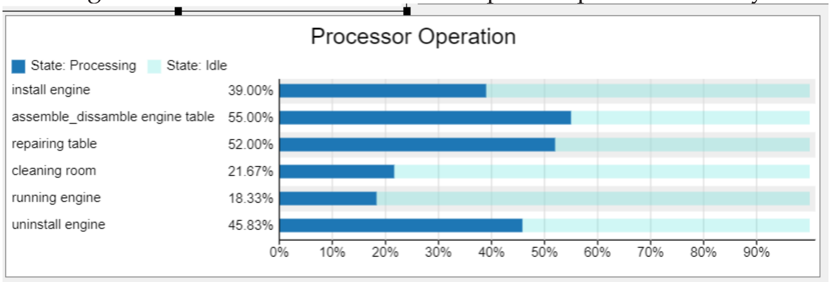
(a) Design 1 (b) Design 2

Figure 10: Operation time of proposed layouts

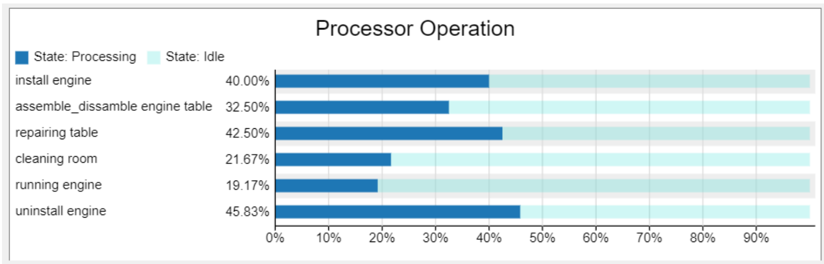


(a) Design 1 (b) Design 2

Figure 11: Number of cars Workshop S can process in a day

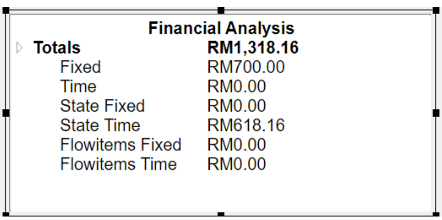


(a) Design 1

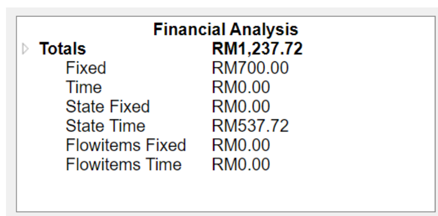


(b) Design 2

Figure 12: Operation state of the proposed layout



(a) Design 1



(b) Design 2

Figure 13: Financial analysis of proposed layouts

Table 1: Comparison of parameters for three different layouts

Layout	Operation time [minutes]	Number of cars can process per day [unit]	Cost [RM]
Current layout	117.35	10	1,504.36
Design 1	103.00	11	1,318.16
Design 2	95.00	12	1,237.72

Design 1 exhibited a seamless workflow without layout-related issues, resulting in improved efficiency. From the simulation, the number of cars finished per day increased by 10% from 10 to 11, showcasing enhanced productivity due to smooth workflow and reduced distances between workstations. The average operation time was reduced by 12.2% from 117.35 minutes to 103 minutes per car. The total cost for a day's operation on Design 1 was reduced by 12.4% from RM1504.36 to RM1318.16, comprising a fixed cost of RM700 and process time cost of RM618.16.

Meanwhile, Design 2 highlighted the rearrangement of the layout, providing more space for the repair station and facilitating a more efficient workflow for mechanics. While running, the simulation indicated that the 12th car was undergoing final inspection, signifying 12 cars were completed. This represented 20% increase from 10 cars of the current layout. The recorded operation time for Design 2 was 95 minutes per car, 19% reduction from 117.35 minutes (current layout). At the end of the simulation, the total cost for a day's operation on Design 2 was RM1237.72, 17.7% decrease over the current layout (RM1504.36), comprising a fixed cost of RM700 and process time cost of RM537.72.

3.2 Comparison of Performance between Current Layout and Proposed Layouts

Performance comparison of the two proposed designs with the current layout was made to determine the most efficient layout in terms of operation time and cost reduction. Table 2 presents the operation time and cost reduction in percentage for both Design 1 and Design 2 in comparison to the current layout. Design 1 achieved 12.2% reduction in operation time, while Design 2 achieved 19.0% reduction. In terms of cost reduction, Design 2 showed a more significant decrease of 17.7%. These reductions inferred that the proposed layouts are more efficient, increasing the number of cars that can be processed in a day by 20% for Design 2 and 10% for Design 1. Overall, the proposed layouts could significantly improve workshop efficiency, particularly in operation time and cost, and are viable for enhancing productivity at Workshop S.

Table 2: Improvements made to the layout design

Layout	Operation time reduction [%]	Cost reduction [%]
Design 1	12.2	12.4
Design 2	19.0	17.7

4.0 CONCLUSION

In conclusion, this study effectively demonstrates that optimizing the facility layout can lead to substantial improvements in operational efficiency and cost-effectiveness. By evaluating Design 1 and Design 2 as the proposed layouts against the current layout at Workshop S, it was found that Design 2 offered the most significant improvement, reducing the average repair time per car by 19.0% and daily operation costs by 17.7%. These enhancements highlight the potential of well-planned layouts to address inefficiencies in space utilization and workflow. The successful implementation of Design 2 at Workshop S not only promises to boost operational performance but also serves as a valuable reference for other workshops experiencing similar layout challenges.

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AUTHOR CONTRIBUTIONS

M.A. Omar: Original Draft Preparation, Data Collection, Software; T.N.A. Raja Mamat: Conceptualization, Methodology, Supervision; R. Jamian: Methodology, Writing-Reviewing; S. Mahmood: Software, Writing-Reviewing and Editing; E. Sari: Validation, Editing.

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