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Production Process Improvement Towards Lean Process Effectiveness using FlexSim Simulation Software

Ahmad Nur Aizat Ahmad[1,*], Md Fauzi Ahmad[1], Raja Zuraidah Raja Rasi[1], Mustaqqim Abdul Rahim[2], Mohd Kamarul Irwan Abdul Rahim[3], Adnan Bakri[4], Fitra Lestari[5]

[1] Department of Production and Operation, Faculty of Technology Management, Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400 Batu Pahat, Johor, Malaysia
[2] Faculty of Civil Engineering Technology, Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia
[3] School of Technology Management and Logistic, Universiti Utara Malaysia, 06010 Bukit Kayu Hitam, Kedah, Malaysia
[4] Facilities Maintenance Engineering Department, Universiti Kuala Lumpur, Malaysian Institute of Industrial Technology, Bandar Seri Alam, 81750 Johor Bahru, Johor, Malaysia
[5] Department of Industrial Engineering, Universitas Islam Negeri Sultan Syarif Kasim, Pekanbaru, Riau 28293, Indonesia

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ABSTRACT

Lean involves optimizing entire value streams to minimize waste and enhance customer value in production practices. Process improvement encompasses the identification, analysis and enhancement of existing business processes to optimize performance and align with best practice standards for a company's products or services. Companies face the imperative of increasing production to meet demand per day. The challenges include enhancing the process effectiveness in the production line. Process effectiveness measures a process's ability to produce desired results, evaluated qualitatively. FlexSim integrates simulation, artificial intelligence, three-dimensional computer image processing and data processing technology. The research objectives include identifying the operational process flow in the study company, proposing a new production process flow using FlexSim simulation software and evaluating the process flow for reducing lead time as part of process improvement. This research adopts a qualitative method, collecting data through observation and interviews. This research helps companies to increase the efficiency and effectiveness of their productivity. The data is analysed using simulation software, focusing on production process improvement to enhance process effectiveness in the PMI's company. The study's outcome reveals a 19.92% reduction in lead time achieved by consolidating processes and eliminating waste, such as waiting time, transportation and product motion. This reduction translates to cost savings and increased profitability, highlighting the positive impact of the implemented changes on the overall performance of the company.

1. Introduction

In today's business landscape, manufacturing companies are compelled to strategize for outcomes that align with economic and environmental demands. Numerous industrial and

* *Corresponding author*
E-mail address: aizat@uthm.edu.my

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production-focused businesses grapple with challenges such as the need to manage overproduction, minimize waste and address the demands of a highly competitive market. This competitive pressure prompts companies to innovate and implement new production and organizational methods, aiming to enhance overall efficiency and competitiveness. The adoption of lean manufacturing practices has proven beneficial for many companies, enabling them to resourcefully manage their operations, improve planning and implement effective waste reduction strategies. The success or failure of lean manufacturing in various industries often hinges on the nature of the product. Manufacturers and suppliers play crucial roles in evaluating and adopting lean techniques and procedures.

The Lean Manufacturing (LM) or Toyota Production System (TPS), pioneered by Toyota, has achieved global adoption due to its advantages in cost, quality, flexibility and rapid response. Lean manufacturing focuses on reducing waste throughout the value chain, prioritizing customer value and optimizing the value stream. According to Lean principles, any resource consumption that doesn't add value to the customer should be modified or eliminated. The fundamental goals of implementing Lean Manufacturing include increasing output, reducing lead times and costs and enhancing quality to provide optimal service to consumers [1].

Productivity emerges as a critical factor in assessing campaign performance, serving as a measure of a company's ability to efficiently produce goods or services. It involves evaluating how well specified resources meet quantitative and qualitative goals within specified time frames. Productivity is often quantified as an index comparing the production of goods and services to the inputs of labour, materials, energy and other resources [2].

In modern organizations, there is a tendency to scale up production to boost capacity without considering the balance of the production line or exploring the potential of existing production lines. According to Shah *et al.,* [3], the challenges in managing diverse product types, raw material specifications and complex demands in the supply chain make production and manufacturing cycles intricate and challenging to oversee. Manufacturers are compelled to address issues related to handling, packaging, storage and shipping to ensure efficiency and reduce overall lead times [4]. According to Jimenez *et al.,* [5], issues related to production processes, declining productivity and quality have historical roots dating back to the Industrial Revolution and the era of mass production. Despite the historical challenges, there is a current lack of comprehensive studies and information regarding production process improvement and process effectiveness, especially when leveraging simulation software like FlexSim.

PMI's company, a food manufacturer in Malaysia, faces the imperative of increasing production to meet demand for various paste flavours. The challenges include enhancing the process effectiveness in the production line. Utilizing simulation software such as FlexSim is seen as a valuable tool to reduce production line time, enhance responsiveness to constant product innovations and improve inventory management. Thus, the purpose of this study is to discover production process improvement toward process effectiveness using FlexSim software to fulfil related objectives such as to:

i. Identify the process flow of the operation in the study company.
ii. Propose a new production process flow by using FlexSim simulation software.
iii. Evaluate the process flow from the process improvement for reducing the lead time.

2. Literature Review

This research holds significant importance as it furnishes vital insights to the management at the factory level regarding the productivity of the production line. A plant simulation model was created and subjected to testing with various parameters using the FlexSim software. The simulation involved a comparison between the simulated outcomes and the actual production data, aiming to assess the efficiency of the production line. The utilization of FlexSim software enhances the reliability of the results, offering a precise point of reference. Additionally, a thorough analysis of the cause and effect of the result findings was conducted. Proposed improvement steps were suggested and tested using the FlexSim software, followed by a comparative analysis of results to identify the most effective solution for the production line. The envisioned improvement steps were anticipated to address bottlenecks and achieve workload balancing across individual workstations. In a broader context, these measures contribute to enhancing the overall efficiency and productivity of the production line's workstations, ultimately leading to cost savings.

2.1 Lean Manufacturing

The concept of LM originated from Toyota Motor Corporation, a prominent Japanese automobile manufacturer. In 1988, Toyota's chief engineer, Taiichi Ohno, developed the TPS as a strategic approach to utilize Japan's limited resources for the company's advancement and survival [6]. In contrast to the American manufacturing model, which employs various machinery and produces a large number of intermediate products, LM focuses on waste reduction and delivering precise quantities that consumers demand, emphasizing timeliness and high quality [7]. Widely adopted by renowned companies like Toyota, Intel, John Deere and Nike, Lean manufacturing or lean production, is a versatile practice applicable across various industries. Many companies, including Toyota, continue to employ the method based on the Toyota Production System. Implementing Lean manufacturing systems can benefit companies adopting Enterprise Resource Planning (ERP), resulting in shorter lead times, reduced operating costs and enhanced product quality [8].

2.2 Productivity

Productivity refers to an individual's capacity to efficiently convert input resources into outputs. Typically measured by the time spent by an employee on a specific activity expected to be completed within a set time limit, productivity is analysed at both the workstation and operation levels, as well as at the overall manufacturing process level [9]. The manufacturing productivity of a resource is defined as the maximum number of items that can be produced within a specified time frame [10].

2.3 Production Process

The term "production process" denotes a comprehensive integrated system comprising multiple processes and equipment within a complex industrial production environment [11]. It involves a series of steps that must be followed to create a product or service. Products possess physical and chemical properties with specific time constraints, while services, in contrast, lack tangible characteristics but have distinct time intervals between production and consumption. Shanmuganathan *et al.,* [12] stated that the appropriate parameter impacts the quality of the product to boost product quality in production line management, hence can improve product quality.

2.4 Industrial Revolution 4.0

Industry 4.0 represents a shift from machine-led to digital-led manufacturing. To ensure a successful transformation, a clear roadmap should be developed and implemented [13]. This transformation aligns with historical shifts in production patterns, from the steam engine to the adoption of electricity, leading up to the digital revolution where computers played a pivotal role in reshaping industry. The ongoing and rapid technological advancements are fundamentally altering societal functions and interactions with the environment [14]. Building on the findings of previous studies by Javaid *et al.,* [15] and Vaidya *et al.,* [16], Industry 4.0 is viewed as a novel production platform. It involves the development of smart and open manufacturing platforms for data applications and industrial networks. In this context, smart factories gain the capability to monitor real-time data, track product status and location and implement production process control instructions. This transformation involves converting standard machines into self-aware and self-learning devices, contributing to overall performance improvement and enhanced management capabilities.

2.5 Simulation Modelling

Simulation modelling involves the creation and analysis of a prototype that mimics the physical model to predict its behaviour and performance in the real world or over time. In this context, a model serves as a representation of the system itself and simulation represents the system's activity during a specific period, illustrating the effects of various variables and the chronological sequence of events. The use of modelling and simulation enables a comprehensive understanding of how a system operates without the need for real-life testing. This approach aids in identifying design errors and mitigating the potential for errors in the system's functioning. Furthermore, it allows for the validation of safety and durability in physical prototypes, resulting in cost reduction and improvements in product and system quality. Simulation models are also employed to analyse system behaviour, supporting decision-making and problem-solving processes. The primary purpose of simulation models is to comprehend system behaviour, particularly in the context of potential system changes. The technique involves simulating dynamic systems using computer models to assess and enhance system performance. Observational data gathered over a specific period is utilized in simulations to predict observed system behaviour. The fundamental steps in simulation modelling encompass model system construction, simulation model construction, model verification, simulation and operation and simulation result output and analysis [17].

3. Methodology

The procedures and steps involved in this study were listed to provide an understandable guideline to ensure the research proceeds smoothly. There are two types of research methodologies. These two types of methodologies are qualitative methodologies and quantitative methodologies. This study will be qualitative, meaning the researcher will focus on observation and interview methods. FlexSim is the most potent, powerful and easy-to-use 3D simulation software. FlexSim lets researcher model and improves existing and proposed systems. The researcher collected data by observation and interview method and applied the data to the FlexSim simulation software to analyse the data and gain results to minimize wasting time and increase the process effectiveness in the food manufacturing industry.

3.1 Research Design and Research Methodology Flow Chart

The research design encompasses a strategic approach to effectively address the identified problem, serving as an instrument and process that guides the collection, measurement and analysis of data information. This method involves critical decisions in selecting appropriate techniques for the study. Analytical research, time study and simulation methods were employed as data collection and analysis instruments, chosen based on the specific issues or problems under consideration. The research took place at PMI's company in Ayer Keroh, Malacca, with data collection relying on the researcher's observation of the production operation and process.

3.2 Data Collection

In order to ensure the research is grounded and substantiated, the collection of recent information from relevant sources is crucial. This research utilized both primary data, obtained through interviews and observation and secondary data, sourced from journals, books, online articles and other reference materials.

3.3 Data Analysis

A qualitative method was employed for data analysis, utilizing a qualitative approach through observation and interviews. The FlexSim software served as the quantitative method for data analysis. This powerful tool facilitated the creation, development and execution of the simulation model. FlexSim specializes in 3D simulation software for various industries, offering applications such as layout planning, production simulation and offline programming. The software provides a visual representation of complex systems, making it easier to understand and analyse. Figure 3 in the appendix displays the interface of the FlexSim simulation software.

3.4 Interview and Observation

Interviews were conducted with key personnel holding significant positions in PMI's company at Ayer Keroh, Malacca. These interviews aimed to gather in-depth information for analysis. Through observation of the production process flow at PMI's company, it was noted that there are 11 workstations involved in the production of asam pedas paste. Prior to simulation, various data were collected, including the number of products produced, the number of operators required in each process, process time and waiting time in every process, recorded in Table 1 and Figure 1.

Table 1
Current process flow of asam pedas paste

Process	Workstation	Operator	Process Time (seconds)	Waiting Time (seconds)	Maximum Time (seconds)
1	Chili Process	1	6607	113	6720
2	Onion Process	1	3262	98	3360
3	Lemongrass Process	1	1514	106	1620
4	Mixing and Grinding Process	2	3302	178	3480
5	Cooking	-	10804	-	10804
6	Filling, Packaging and Labelling Process	2	2949	231	3180
7	Sterilization Process	1	2402	418	2820
8	Cooling Process	1	3011	349	3360
9	Quality Control and Quality Assurance	1	2116	179	2295
10	Warehouse/Storage	-	-	-	-
11	Shipping	-	-	-	-
Time for one cycle for one batch			35967	1672	37639

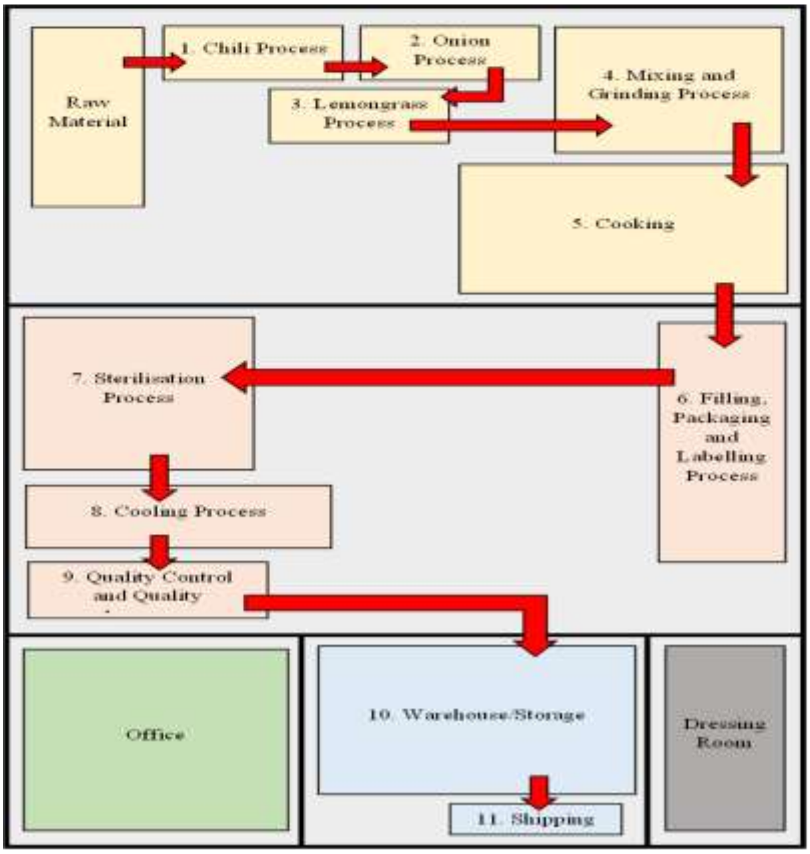


Fig. 1. Current process flow of asam pedas paste layout

4. Results and Discussion

The findings of this study highlight challenges encountered in the production line of company products, specifically focusing on minimizing waste in transportation, waiting time and product motion during production. Lean principles and simulations through the FlexSim simulation software application were employed to address these issues. The FlexSim software was used to simulate the new process flow, aiming to acquire relevant information for subsequent analysis.

4.1 Process Improvement

Upon analysing the data presented in Table 1, it becomes evident that certain processes can be consolidated. For instance, processes 1, 2 and 3 can be amalgamated into a single process. Moreover, some processes, such as filling, packaging and labelling, exhibit extended process times due to manual execution. To enhance the efficiency and effectiveness of the asam pedas paste production process flow, process improvements will be implemented. These improvements are designed to reduce and eliminate waste, particularly in areas such as waiting and movement.

4.1.1 Rearrange the process flow to improvement process effectiveness

Examining the entire process flow as depicted in Figure 1, this study identifies the need for an improved arrangement of the asam pedas paste production process flow to mitigate waiting time waste when the product transitions between stations. The researchers' analysis suggests that several unnecessary workstations should be modified to enhance the current process's effectiveness and efficiency.

4.1.2 Reallocated the operators to improve process effectiveness

This study advocates for the reallocation of operators in the asam pedas paste production process flow to enhance overall process effectiveness. This recommendation is based on the information presented in Table 4, detailing the process flow. The researchers' analysis indicates that certain workstations should be reassigned to minimize time and enhance process effectiveness.

4.1.3 Implementing automated machine to improve process effectiveness

Upon observing the manual nature of most production processes in PMI's company, the researchers note that this manual approach leads to prolonged product completion times. The introduction of automated machines is proposed to streamline the production process, improving its overall effectiveness and reducing both time and the need for operators. Researchers' analysis suggests implementing automated machines in specific workstations to optimize the process.

4.1.4 Implementing the conveyor to improve process effectiveness

The researchers observed prolonged waiting times between processes in PMI's company. The proposal to introduce conveyors to the production line aims to eliminate waiting times between processes, thereby enhancing overall process effectiveness.

4.2 New Process Flow

Utilizing data gathered from the existing state of the process flow at PMI's company, the researcher proposed a revised process flow to enhance production and optimize process efficiency. The initial observation of the production process flow at PMI's company identified 11 processes necessary for asam pedas paste production. Following the improvements implemented in the production process flow, the revised version now involves 9 workstations in the production of asam pedas paste. Table 4 details the updated production process flow for asam pedas paste, concurrently reflecting the reassigned number of workers for each process. Additionally, the recalculated process time, waiting time and maximum time in seconds are presented in Table 2.

Table 2
New process flow of asam pedas paste

Process	Workstation	Operator	Process Time (seconds)	Waiting Time (seconds)	Maximum Time (seconds)
1	Process of Chili, Onion and Lemongrass	3	6420	101	6521
2	Mixing and Grinding Process	3	3120	-	3120
3	Cooking	-	10804	-	10804
4	Filling, Packaging and Labelling	-	2000	-	2000
5	Sterilisation Process	-	2596	-	2596
6	Cooling Process	1	3196	28	3224
7	Quality Control and Quality Assurance	2	1709	167	1876
8	Warehouse/Storage	-	-	-	-
9	Shipping	-	-	-	-
Time for one cycle for one batch			29845	296	30141

Figure 2 shows the result of the simulation run with the FlexSim simulation software for the improved process flow layout.

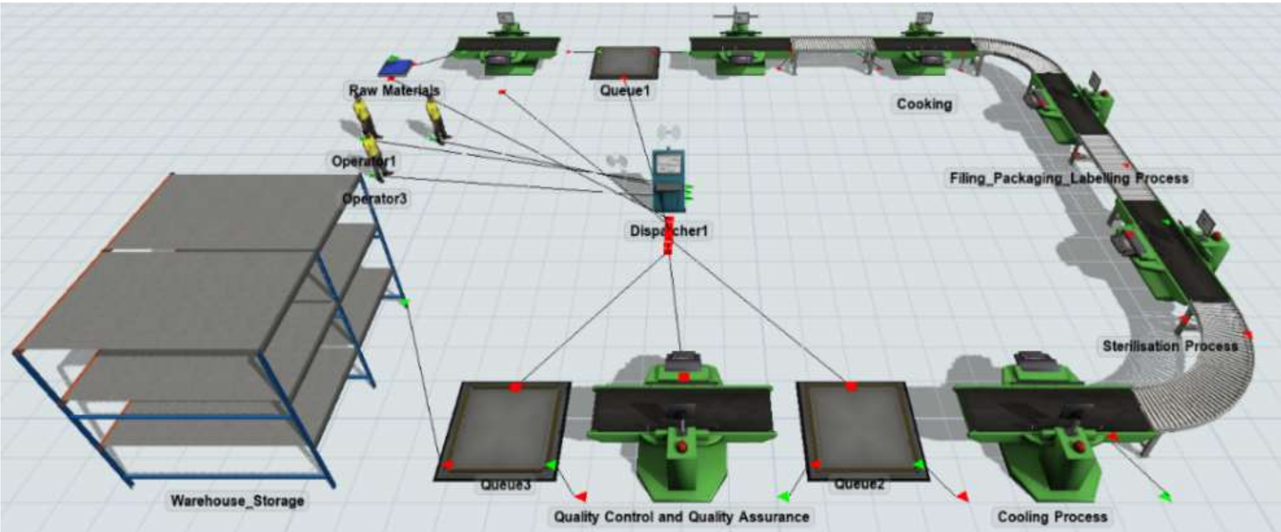
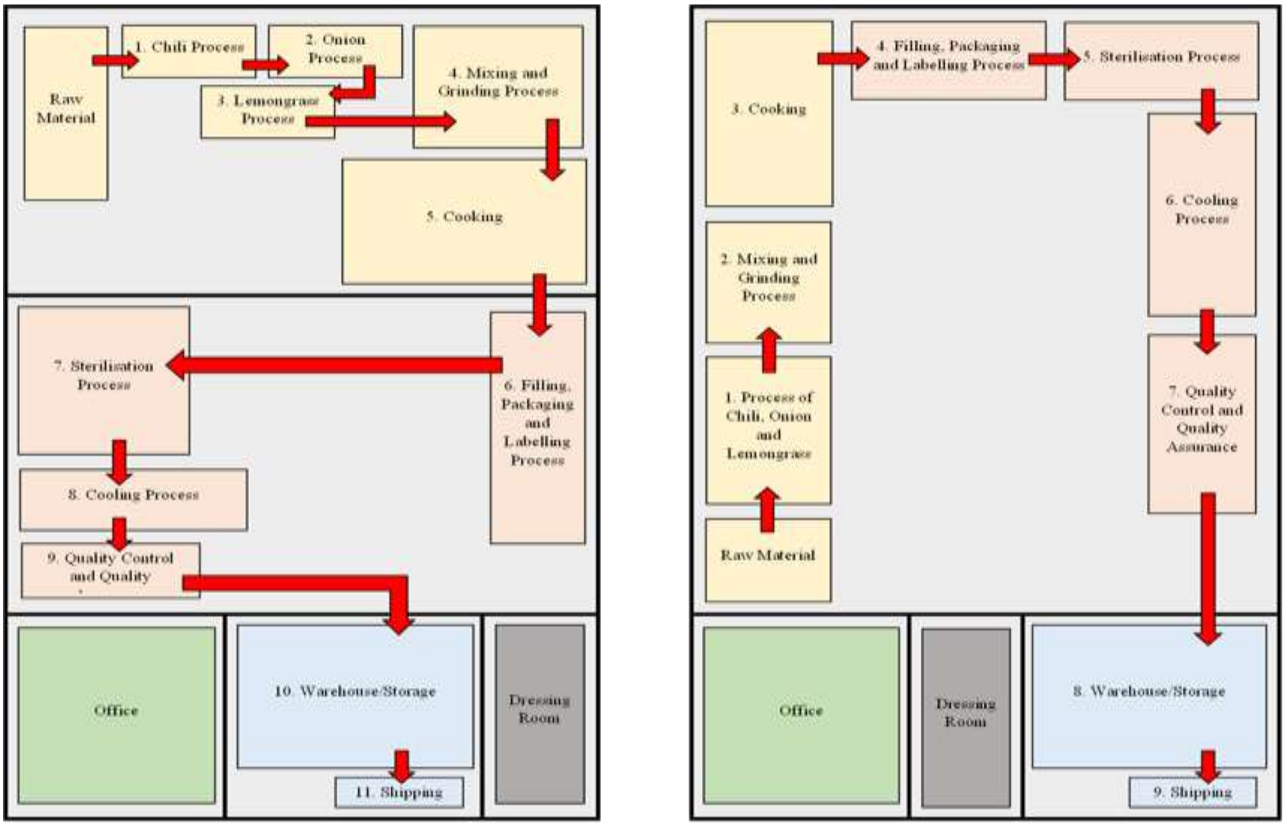


Fig. 2. New process flow of asam pedas paste layout using FlexSim simulation software

4.3 Comparison of Current Process Flow and New Process Flow

Based on the current process flow layout, the researcher had created a new process layout to improve the process effectiveness. The current process layout and new process layout can be shown in Figure 3.



Before After

Fig. 3. Current and new process layout

Utilizing the data presented in Tables 3 and 4, the researcher can compare it with the outcomes of the enhanced process achieved through FlexSim simulation software, assessing the effectiveness of the newly created production flow in comparison to the existing process. The comparison and integration of the current process flow with the new process flow are illustrated in Table 3.

Table 3
Comparison current process flow and new process flow

Comparison and Combination Table							
Current Process Flow			New Process Flow				
No.	Workstation	Lead Time (Seconds)	No.	Workstation	Lead Time (Seconds)	Lead Time Reduction (Seconds)	Lead Time Reduction (%)
1	Chili Process	6720	1	Process of Chili, Onion and Lemongrass	6521	↓ 5179	↓ 44.26
2	Onion Process	3360					
3	Lemongrass Process	1620					
4	Mixing and Grinding Process	3480	2	Mixing and Grinding Process	3120	↓ 360	↓ 10.34
5	Cooking	10804	3	Cooking	10804	0	0.00
6	Filling, Packaging and Labelling Process	3180	4	Filling, Packaging and Labelling Process	2000	↓ 1180	↓ 37.11
7	Sterilisation Process	2820	5	Sterilisation Process	2596	↓ 224	↓ 7.94
8	Cooling Process	3360	6	Cooling Process	3224	↓ 136	↓ 4.05
9	Quality Control and Quality Assurance	2295	7	Quality Control and Quality Assurance	1876	↓ 419	↓ 18.26
10	Warehouse/Storage	-	8	Warehouse/Storage	-	-	-
11	Shipping	-	9	Shipping	-	-	-
Total Lead Time		37639	Total Lead Time		30141	↓ 7498	↓ 19.92

4.4 Comparison Among the Processes

Examining the data presented in Table 4, it is evident that certain processes entail a brief processing time, while others demand a more extended period. Consequently, processes sharing similar steps should be amalgamated to ensure a balanced process time across each step in the overall process flow. The comparison between the existing processes and the proposed new processes is detailed in Table 4.

Figure 4 shows the number of workstations before and after the process flow. The number of workstations decreases from 11 workstations to 9 workstations.

Table 4
Comparison current processes and new processes

Current Process	Workstation	Improved Process
1	Chili Process	1
2	Onion Process	
3	Lemongrass Process	
4	Mixing and Grinding Process	2
5	Cooking	3
6	Filling, Packaging and Labelling Process	4
7	Sterilisation Process	5
8	Cooling Process	6
9	Quality Control and Quality Assurance	7
10	Warehouse/Storage	8
11	Shipping	9

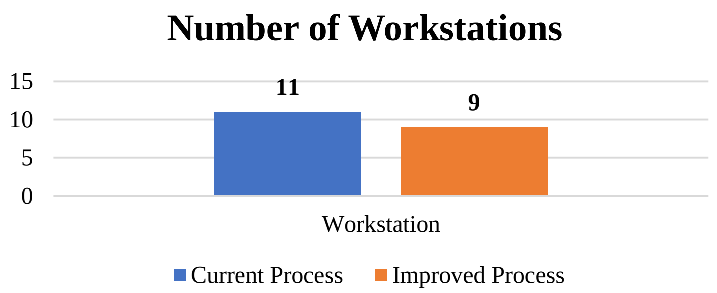


Fig. 4. The number of workstations before and after

In Figure 5 and 6, the process time for each workstation is illustrated both before and after implementing the revised process flow, highlighting the achieved process time reductions. Specifically, the processing times for chili, onion and lemongrass decreased from 11,700 seconds to 6,521 seconds, marking a significant reduction of 44.26%. The Mixing and Grinding Process saw a decrease from 3,480 seconds to 3,120 seconds, reflecting a 10.34% reduction. It's noteworthy that the cooking process time remained unchanged to preserve product quality. In the Filling, Packaging and Labelling Process, the current process time of 3,180 seconds decreased to 2,000 seconds, demonstrating a notable reduction of 37.11%, attributable to the utilization of automated machinery for these tasks.

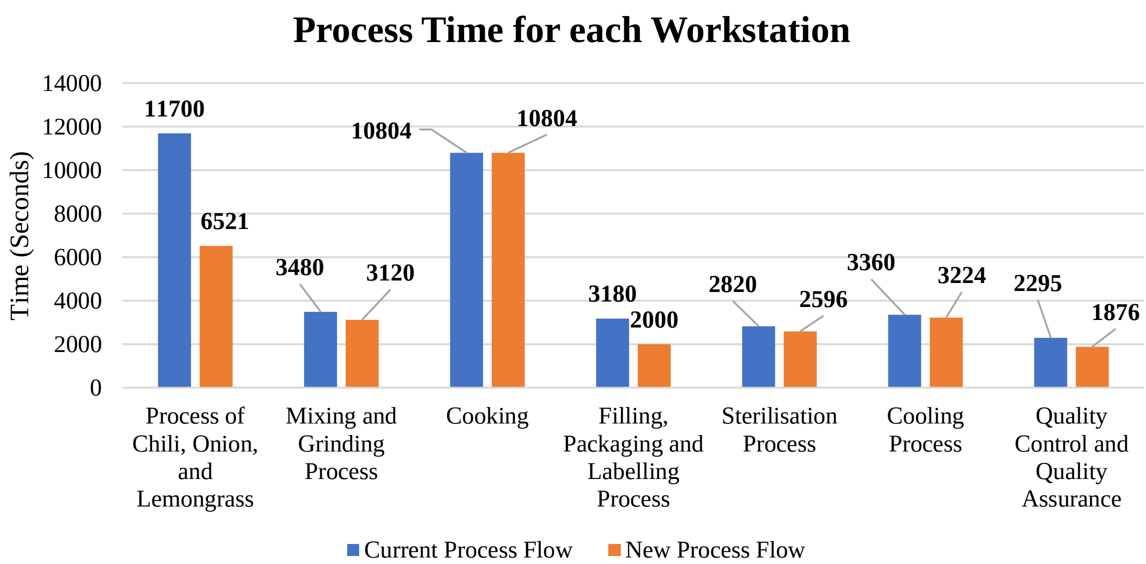


Fig. 5. The processing time for each workstation before and after

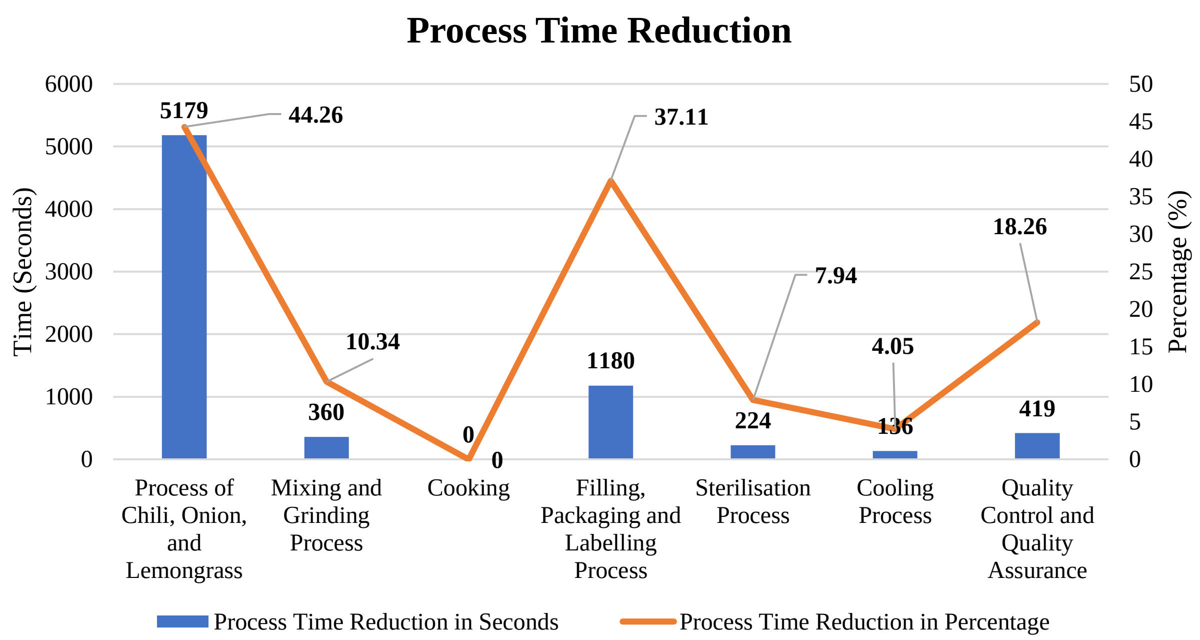


Fig. 6. Process time reduction

Moving on to the Sterilization Process, the current process time of 2,820 seconds decreased to 2,596 seconds, indicating a reduction of 7.94%. The Cooling Process, with a current process time of 3,360 seconds, saw a decrease to 3,224 seconds, resulting in a 4.05% reduction. Finally, in the Quality Control and Quality Assurance stage, the current process time of 2,295 seconds decreased to 1,876 seconds, showcasing a reduction of 18.26%. These improvements collectively contribute to enhanced efficiency and streamlined operations in the overall production process.

4.5 Comparison Among the Allocation of Operators

Based on the data collected in Table 4, it is not difficult to see that only one or two operators are required for each process. However, some processes require a shorter process time and some processes require a longer process time. Therefore, operators should be reallocated to balance the process time for each process in the process. The operator allocation for the current and new processes is shown in Table 5.

Table 5
The operator allocation for the current and new processes

Current Process	Operator	Workstation	Operator	Improved Process
1	1	Chili Process	3	1
2	1	Onion Process		
3	1	Lemongrass Process		
4	2	Mixing and Grinding Process	3	2
5	-	Cooking	-	3
6	2	Filling, Packaging and Labelling Process	-	4
7	1	Sterilisation Process	-	5
8	1	Cooling Process	1	6
9	1	Quality Control and Quality Assurance	2	7
10	-	Warehouse/Storage	-	8
11	-	Shipping	-	9

4.6 Comparison of the Total Lead Time and Total Waiting Time

From the result obtained from the FlexSim simulation software, it was clearly shown that the company had decreased the total lead time of production and the waiting time of the production. The comparison of the total lead time and the waiting time in each batch are shown in Table 6.

Table 6
Comparison of total lead time and total waiting time

Comparison Table			
Categories	Before (Current)	After (New)	Reduction (%)
Total Lead Time	37639 seconds	30141 seconds	↓ 19.92
Total Waiting Time	1672 seconds	296 seconds	↓ 82.30

Table 4 provides an overview of the entity components in both the current and new production scenarios after running simulations with FlexSim software. Notably, the table highlights the disparity between total lead time and total waiting time following the implemented improvements. The comparative analysis demonstrates a decrease in both total lead time and total waiting time, indicating the efficacy of the implemented enhancements. The findings from this comparison table suggest that the improvements made are beneficial for the company, contributing to increased process effectiveness. It can be inferred that the total lead time in the improved process flow surpasses that of the current process flow in terms of efficiency and the waiting time has either been reduced significantly or eliminated. These positive outcomes are visually represented in Figures 7 to 9. Based on Figure 7, the total lead time of the current process flow and new process flow is 37639 seconds and 30141 seconds respectively.

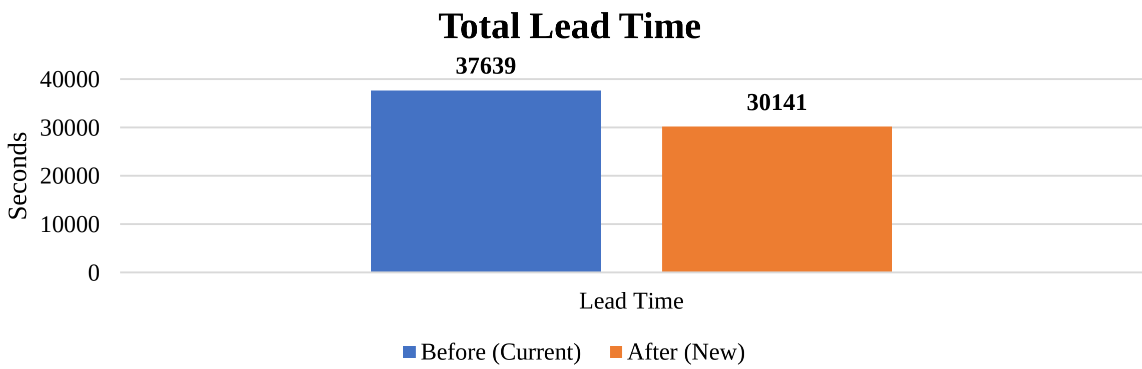


Fig. 7. Total lead time before and after in production line

Based on Figure 8, the total waiting time of the current process flow is 1672 seconds and the total waiting time of the new process flow is 296 seconds.

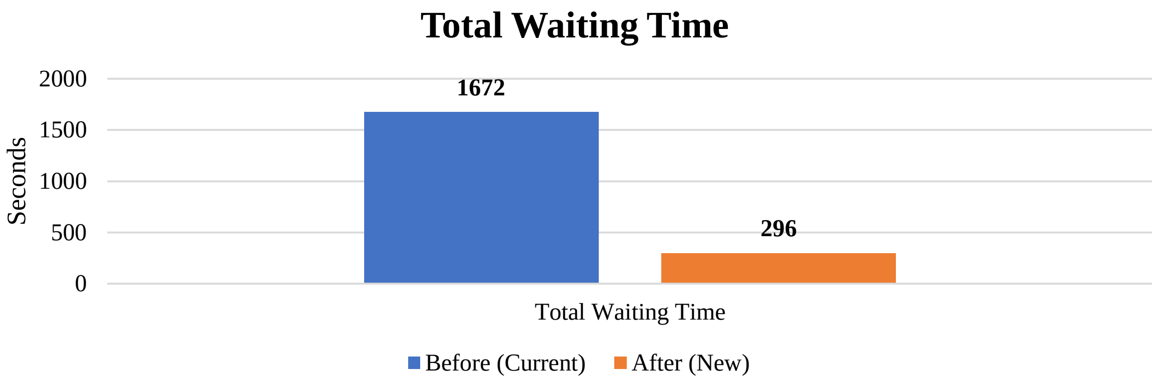


Fig. 8. Total waiting time before and after in production line

In Figure 9, the reduction in lead time following the optimized process flow is noteworthy, with a difference of 7,498 seconds and a reduction rate of 19.92%. This improvement signifies a faster processing time compared to the current process flow. Simultaneously, the waiting time reduction after implementing the revised process flow is even more remarkable, with a difference of 1,376 seconds and a reduction rate of 82.30%. This substantial decrease in waiting time underscores the significant efficiency gains achieved through the implemented process enhancements.

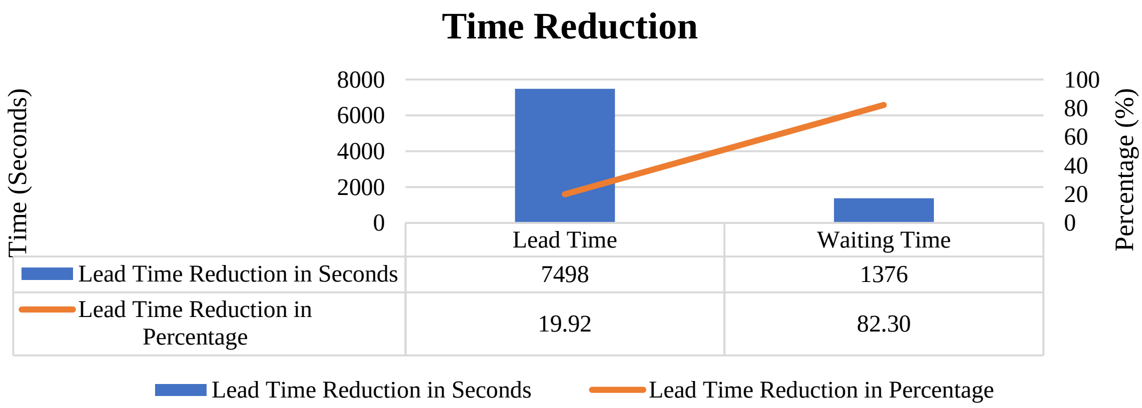


Fig. 9. Time reduction

4. Conclusions

In summary, the implementation of lean management, coupled with the identification of existing issues and elimination of non-value-added processes such as transportation, waiting and product motion, successfully achieved all three research objectives. The synergy of lean management principles and the application of FlexSim simulation software played a crucial role in meeting these objectives. Lean management's focus on waste reduction and enhanced process flow effectiveness complemented the 3D modelling capabilities of FlexSim, ensuring a comprehensive approach.

While FlexSim proved valuable for visualizing an improved process flow, it is imperative to validate that the proposed enhancements are not only conceptually sound but also functionally and practically applicable to the actual production process. The substantial 19.92% reduction in total lead time before and after the improvements is a significant achievement, with far-reaching implications for the company. This reduction translates to cost savings and increased profitability, highlighting the positive impact of the implemented changes on the overall performance of the company.

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