Increasing Efficiency in the Process of Loading Goods into Containers through Lean Automation Concepts: A Case Study of 25kg Tapioca Starch Packaging

Patitta Kamjumpol, Nara Samattapapong
School of Industrial Engineering
Institute of Engineering
Suranaree University of Technology
Nakhon Ratchasima,
Thailand
ladypatitta@gmail.com, nara@sut.ac.th

Abstract

The tapioca starch industry is critical to Thailand's economy and is constantly developing to meet global market demands. Tapioca starch producers must refine their delivery strategies to align with customer demands efficiently, with a specific focus on optimizing the container-loading process, which plays a vital role in enhancing product delivery. Therefore, the objective of this study is to determine more efficient methods to load products into containers using the Lean Automation concept. In this study, the researchers examined the shipping process of a tapioca starch factory and found that the current loading process required 82.89 minutes per container. To enhance efficiency, the researchers employed tools such as Value Stream Mapping (VSM), Cause and Effect Diagrams, and the FlexSim program to simulate the loading process and identify areas for improvement. The results of the simulation modeling of the container loading process revealed that after implementing improvements, the loading time for goods into containers could be reduced from 82.89 minutes per container to 77.73 minutes per container, indicating a decrease of 5.16 minutes per container or a 6.23 percent improvement. When loading products into two containers simultaneously, the manpower required can be reduced from six to five. Additionally, it was determined that the number of forklifts in use could be reduced from two to one. The findings of this study offer valuable insights for planners engaged in warehouse and logistics operations. They can serve as a practical guide for improving the efficiency of loading goods into containers.

Keywords
Tapioca Starch, FlexSim simulation, The container loading process, and Value steam mapping (VSM)

1. Introduction
Thailand's tapioca starch industry is steadily growing to meet the demands of both domestic and international markets because it serves as a key ingredient in various sectors, including pharmaceuticals, food production, paper manufacturing, and cosmetics. The tapioca starch manufacturing industry is required to engage in development in order to successfully meet the rising demands of customers and maintain competitiveness within the market. In the current situation, both labor costs and consumer quality expectations are rising. To maximize production efficiency, manufacturers must implement value-added techniques or technologies. This includes enhancing processes from the arrival of raw materials to product shipment to ensure that consumers receive high-quality and demand-satisfying products.

The data from the cassava starch factory was studied as a case study. It was discovered that there was a process of loading products into containers in the shipping process that involved activities that did not add value to the work process. This research applied lean automation principles to enhance delivery process efficiency. It involves creating a value stream map to identify non-value-added activities, utilizing lean tools Cause and Effect Diagrams to analyze the causes of process issues, and employing the FlexSim software to model and analyze the container loading process before and after workflow improvements.

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2. Literature Review

The application of Lean, Six Sigma, and Lean Automation methodologies improved the automotive sheet metal forming process in the study by Tantiphanwadi et al. (2020). These resulted in heightened operational efficiency and a reduction in production duration, effectively transitioning the process from its original configuration to a state of semi-lean automation. In addition, Kolberg and Zühlke (2015) have described the integration of existing lean manufacturing technologies and automation. Also known as Lean Automation, it also discusses the important cornerstones of Industry 4.0.

Furthermore, Habib et al. (2020) proposed using a lean manufacturing approach through value stream mapping (VSM) to improve the organization's overall performance. The aims of this research were to enhance performance by aligning with key performance indicators (KPIs), reducing waiting times, lowering customer complaint rates (CCR), increasing production units per labor hour (UPLH), and utilizing equipment efficiency (UEE) to assess productivity gains across various processes. Similar to Kraiwong and Setamanit (2020) uses Value Stream Mapping (VSM) to analyze operational flows and bottlenecks of the wood substitute loading process.to identify ways to reduce non-value added time of loading process. Jairuk et al. (2021) discusses the application of Lean concepts to find waste hidden in Warehouses in the Oil and Gas Industry. Then use the fishbone diagram to analyze the causes of waste to determine measures and prevention guidelines.

In addition, Yamazaki et al. (2017) introduced a method for designing a lean automated material handling system aimed at minimizing waiting time. This approach relies on the principles of lean automation, which emphasize the removal of non-value-added steps and waste from the material handling system through the application of cluster analysis and genetic algorithms (GA).

Furthermore, the researcher investigated modeling and simulation studies and discovered. Chandrakumar et al. (2016) recommendation to use lean manufacturing systems in conjunction with FlexSim simulations to improve and speed up the transfer of goods. The simulation results indicate that there are significant waiting times, employee idle periods, and long queues. To address these issues, the Lean concept was introduced to reduce waiting times, minimize employee downtime, and shorten queue lengths. Mhoraksa et al. (2020) created a drinking water production process model using FlexSim simulation software. This research aims to reduce drinking water production process production time due to maximum production time. Syahputri et al. (2021) explain that calibration and validation are required when modeling a situation in order to analyze its current state.

In conclusion, these studies highlight the efficacy of lean methodologies in improving various industrial processes, from automotive manufacturing to goods transfer, emphasizing the importance of calibration and validation in modeling and simulation research.

3. Methods

This research applied the concept of Lean Automation to study and analyze the process of loading goods into containers, with the objective of identifying and implementing improvements in the work procedures as follows:

Step 1: Creating a value stream map to identify non-value-adding activities in the work process.

Step 2: Analyzing the cause of work process waste using the cause - effect diagram and the why - why analysis principle.

Step 3: Developing methods to improve workflow.

Step 4: Designing a simulation model of the container loading process and analyzing the results before and after using FlexSim to improve the workflow.

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3.1 Value Stream Mapping

This procedure involved the developing of a value stream mapping to pinpoint non-value-adding activities within the current container loading process. The analysis revealed two specific points that required development and improvement: Point 1: waiting time for loading products into containers, and Point 2: time taken to load products into containers. These areas need improvement because they take up more time compared to other steps in the process.

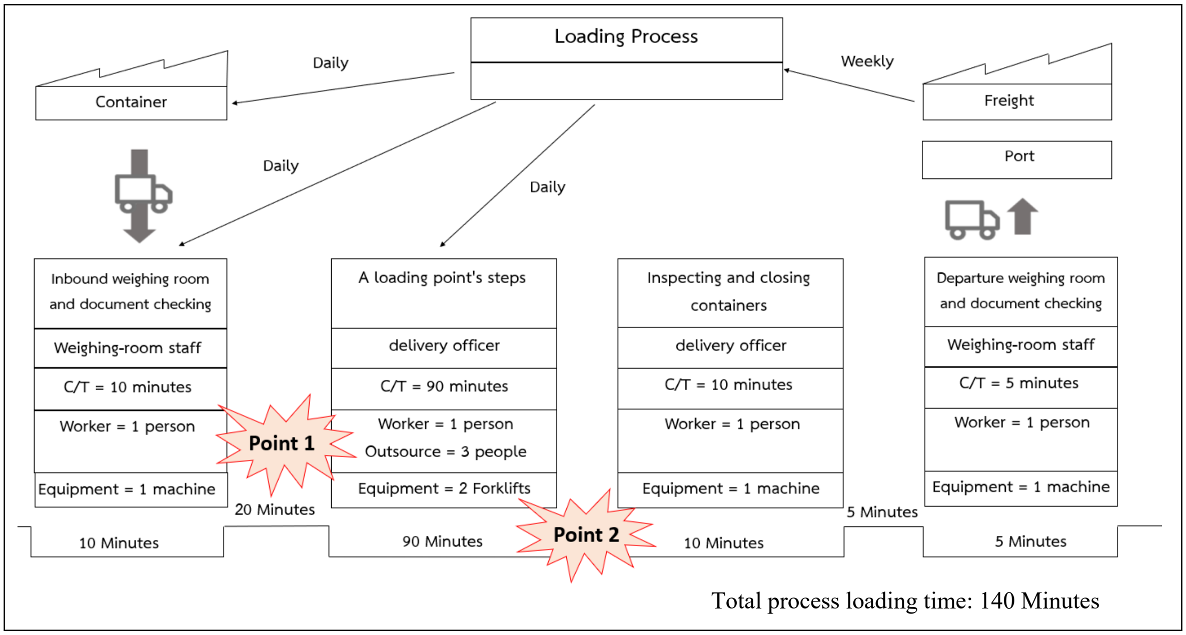

Figure 1. Value stream mapping for the current container loading process in the case study factory.

3.2 Cause & Effect Diagram

Based on the findings from the Section 3.1 analysis, two specific areas emerged as requiring improvement. During this phase, the researchers employed a cause-and-effect diagram in combination with the why-why analysis principles to investigate the reasons behind the extended working and waiting times compared to other steps. This investigation revealed the following root causes:

1. Machinery and Equipment: The issue in this area arises due to an inadequate number of forklifts available for loading products into containers, especially when multiple transport vehicles arrive simultaneously for loading. This shortage of equipment leads to delays and inefficiencies in the loading process.

2. Labor Aspect: The constant lifting of heavy objects is a primary problem contributing to the extended working and waiting times. Additionally, a reduction in the number of laborers available to handle the lifting task has become the issue. Furthermore, the aging workforce has resulted in decreased work efficiency, as older employees may not be as physically capable as they once were, leading to slower operations.

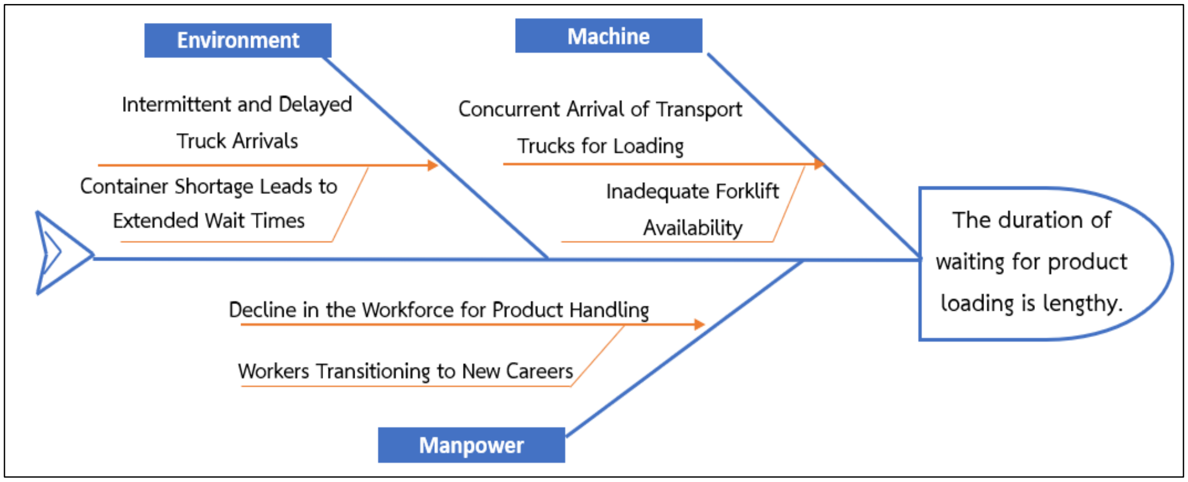

Figure 2. Analysis of waiting times for loading products into containers through a Cause-and-Effect Diagram and Why-Why Analysis.

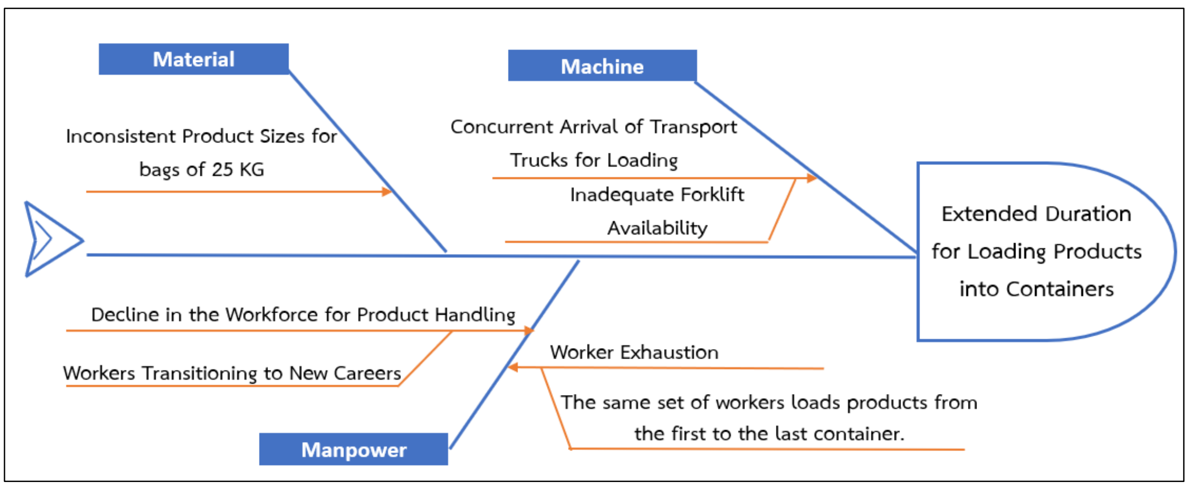

Figure 3. Analysis of time taken for loading products into containers through a Cause-and-Effect Diagram and Why-Why Analysis.

3.3 Creating and Analyzing Simulation Model of the Container Loading Process Before and After Workflow Improvement Using FlexSim

3.3.1 Data Collection and Analysis for Container Loading Process: this step involves surveying, collecting, and analyzing data on the process of loading packages into containers for the purpose of determining modeling parameters. Manpower and machine data were collected, providing timely information for accurate analysis.

Table 1. Time taken to load packages into containers in the current workflow

Sequence of lifting (No. of Package)	Time required to stack packages in containers (seconds)				
	Container 1st	Container 2nd	Container 3rd	Container 4th	Container 5th
1-60	390	385	389	390	388
61-120	392	394	392	390	390
121-180	379	382	385	388	389
181-240	382	378	386	382	391
241-300	380	380	377	385	388
301-360	370	386	380	379	384
361-420	372	375	380	376	380
421-480	369	378	375	380	377
481-540	370	368	371	367	370
541-600	355	363	358	361	367
601-660	360	358	362	360	362
661-720	356	361	360	361	345
721-756	345	340	355	366	347
total	4,820 seconds	4,848 seconds	4,870 seconds	4,885 seconds	4,878 seconds
	80.3 minutes	80.8 minutes	81.2 minutes	81.4 minutes	81.3 minutes

A suitable simulation process requires comparison and validation in accordance with actual practice in reality. Through a comparative analysis using FlexSim, the time required for loading products into containers was tested and assessed for accuracy. The acceptable deviation was set at 5 percent. Subsequently, the values derived from the model were compared with the real operational values using Equation 1. The findings indicated an overall deviation of 2.14 percent. As a result, the model is close to meeting the acceptable criteria and can be used to simulate improvements and solve problems.

$$\%Difference = \frac{[E-S]}{S} \times 100 \qquad (1)$$

3.3.2 Creating the Simulation Model of the Current Workflow.

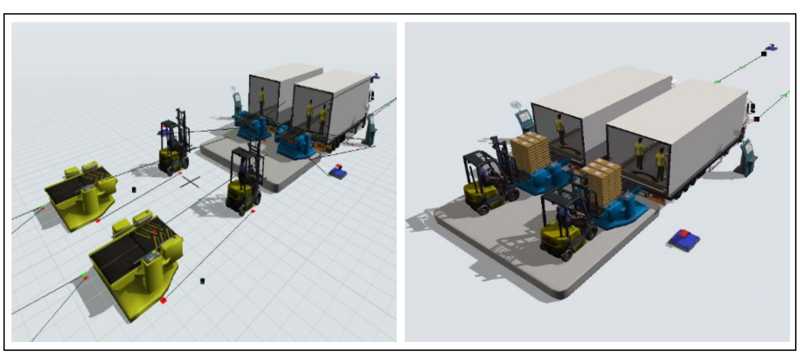

Figure 4. Simulation model of current situation.

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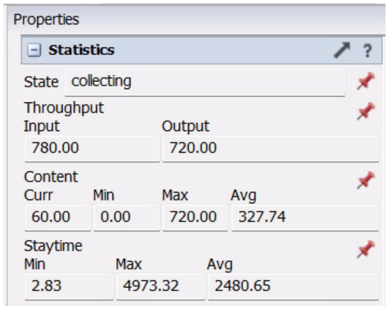

Figure 5. Time taken to load products.

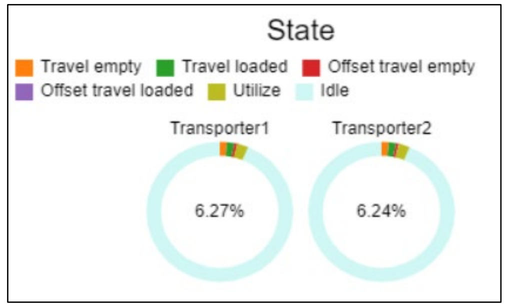

Figure 6. Results of forklift utilization percentage and idle time.

Figures 4 and 5 illustrate a simulation model created from the current workflow for use in analysis to identify ways to improve the work process. Furthermore, Figure 6 reveals that the use of the two forklifts was inefficient.

3.3.3 Creating a Simulation Model After Workflow Improvements.
This study focuses on improving operational processes through the use of lean automation, a combination of lean principles and modern Industry 4.0 technology. As such, the study implemented a conveyor belt system to optimize efficiency.

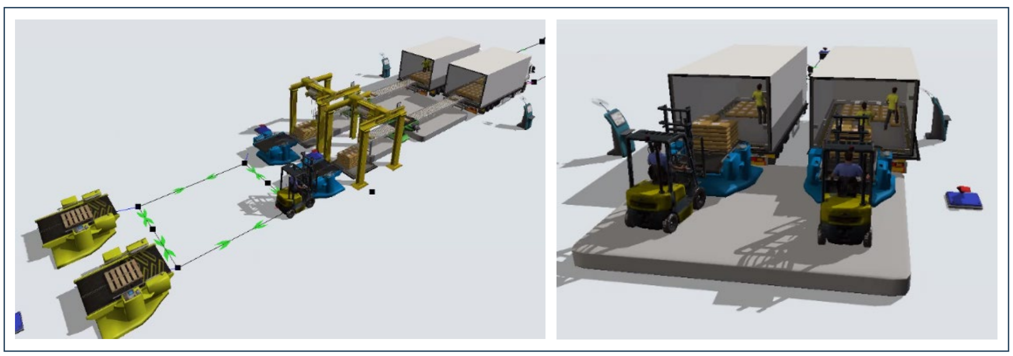

Figure 7. Simulation model after improvement.

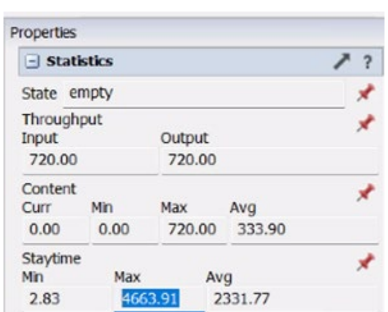

Figure 8. Time taken to load products after improvement.

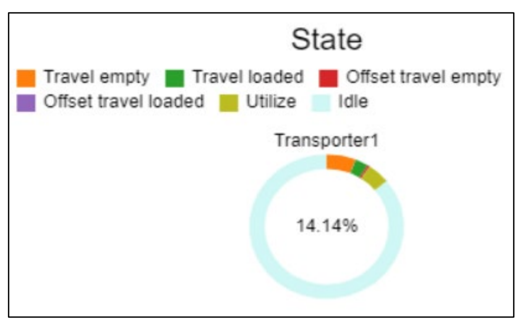

Figure 9. Results of forklift utilization percentage and idle time after improvement.

4. Results and Discussion

The objective of this study is to enhance and optimize the efficiency of the product loading process into containers through the implementation of Lean Automation principles. This could be achieved by creating a model of the loading process and conducting a comparative analysis of the outcomes before and after implementing workflow improvements using the FlexSim software. It was found that the process of loading products into containers currently takes 82.89 minutes per container. After improvements, loading times can be reduced from 82.89 minutes per container to 77.73 minutes per container, or a reduction of 5.16 minutes per container, or 6.23 percent. When simultaneously loading products into two containers, the workforce can be reduced from six to five, and the number of forklifts used can be reduced from two to one.

Table 2. Comparative analysis results from simulation models.

No.	Simulation Model	Loading Time per Container (minutes)	Loading Products into Two Containers Simultaneously	
			Number of Workers (persons)	Number of Forklifts (forklift)
1	The current loading process	82.89	6	2
2	The improved loading process	77.73	5	1

5. Conclusion

The findings of modeling and simulation research can be used to guide improvements and increase the efficiency of the container loading process. It was discovered that using a product conveyor belt can help reduce time, labor, and the number of forklifts used in the work process. This is another method for increasing the efficiency and competitiveness of businesses. When implementing study results into practice and future development, additional variables such modifying equipment or tools to be automated should be taken into consideration.

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Biographies

Patitta Kamjumpol received the B.E (2013) degrees in Transportation Engineering from the Suranaree University of Technology, Thailand. She is currently a production planner with Kyocera AVX components (Bangkok) ltd., Nakhon Ratchasima, Thailand.

Nara Samattapapong is an Assistant Professor in the Department of Industrial Engineering, Faculty of Engineering at Suranaree University of Technology. He holds a bachelor's degree in Industrial Engineering from Suranaree University of Technology and holds a Master's and Ph.D. in Mechatronics from the Asian Institute of Technology.

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