Simulation-Based Application for Improving Carton Production Process

Nara Samattapapong and Thiti Mhoraksa

1 Introduction

The industrial sector is continually undergoing changes at the moment. Regardless of how much technology rapidly advances, cartons continue to be used as packaging for electronics, automobile parts, and a variety of other industries. It continues to be widely used today because of the qualities that can protect the goods from scratches and damage, as well as its lightness. According to the case study factory's analysis, the company is a contract packaging company. The company receives raw materials from suppliers and applies made-to-order models to cut them into pieces based on the customer's requirements. Each client has specific product requirements, so each customer's product is manufactured using a specific production technique. It means that working systems are arranged in a variety of ways. As a result, the work system must be structured methodically and the number of machines and employees has to be suitably increased or decreased to keep production running and the project has to finish on time. According to the company's goal, "the company will produce the package in accordance with the specific needs and inventing the evolution of materials at a rapid rate in order to reduce the waiting time. The quality and punctuality must be consistent. The objective is to keep all of the partners' supply chains running smoothly. New innovations are continuously introduced as effective tools for

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developing and creating something better, more flexible, lighter, and more environmentally friendly. The research team collaborated together to design the work process and system placement, so that they could operate more efficiently. It would have the ability to increase production. The objective was to enhance efficiency and reduce waste in the carton manufacturing process by integrating simulation techniques into the process design.

2 Theoretical Framework

Definition of Simulation

There are researchers who have studied and discussed simulations in various contexts, as follows:

Kelton et al. (2007) suggested that simulation is a method and application that uses computer software to simulate the behavior of a real system. Pisuchpen (2008) said that simulation is defined as the process of building a model of a real system and then performing experiments to understand how the real system behaves. The experiment's results will next be evaluated before being used to solve problems in real-life situations. Surachetkiati (2001) said that the simulation is the process of designing a model of a real system and the experimental design in this model and then understand system behavior and estimating the variables important to the operation within the system.

3 Gen

It is a manufacturing philosophy in practice. This is a concept and practice that has been established as a model for the manufacturing sector. Based on the principle of "don't trust anyone," this approach can generate consistency between real circumstances and scenarios in production. It consists of (1) GENBA is the actual place, (2) GENBUTSU is the actual production piece, and (3) GENJITSU is the fact (Chalermjirarat 2006).

7 Waste

Taiichi Ohno, the founder of the Toyota production system, divides waste into seven categories: overproduction, waiting, transportation, inventory, movement, unnecessary processes, and waste (Praison 2011).

3 Related Studies

From the relevant research studies, it was found that computer-based simulations have been applied to the allocation of the number of employees to reduce labor costs and to improve employee efficiency. Kengpol and Youngswaing (2015) have adopted the principles of concurrent engineering and simulations used to allocate employees and adjust the production process of the oil pipe production process. It was found that the new production process can reduce the number of employees from 4 to 2 people. Moreover, it also reduces the machines used in the production process from 2 machines to 1 machine. Therefore, the remaining machines and staff can be allocated to support the new production line. As a result, there are benefits such as increasing production capacity by 50%, lowering the investment cost of purchasing pipe bending machines, and lowering the annual cost of recruiting employees. Samattapapong (2018) has employed simulation modeling to investigate the problem and to develop a better cassava starch packing process. The outcomes were compared to those of the common practice. The best alternative was shown to be capable of reducing testing time by 19.02%, sealing time by 17.99%, transit time by 47.18%, and moving time by 34.10%. Furthermore, it was able to cut the workforce by three individuals.

The efficiency and management system have been improved by using a situational model. Mhoraksa et al. (2020) have used the model to examine the production system and enhance the drinking water manufacturing process. As a consequence, the information and Flexsim® were utilized to construct a model. It was discovered that a bottleneck existed in the filling process. As a result, three solutions were devised to address the issue. After putting each alternative to the test, the findings revealed a 36.61% reduction in manufacturing time. Ghiyasinasab et al. (2018) have also employed lean approaches and simulations to improve their work. Kusoncum et al. (2018) have use the model to improve mill yard management that aims to reduce the time in the system for sugarcane transport vehicles. As a result, two solutions were devised to address the issue. After putting each alternative to the test, the findings revealed a 11.39% reduction in the system time. Klinlek et al. (2020) have use the model to increase the quantity of products and the quality of the working process. Jarernram and Samattapapong (2018) have used the model to production scheduling and to search makespan optimization of parallel machine production scheduling, the production process of this plant is parallel machine. Phanindra et al. (2019) have used the model to improve its productivity, optimizing it, and increase the overall efficiency of a Plant. The paper illustrates that the system can be optimized by high work station utilization through managing bottlenecks with the addition of buffers. Chanthakhot and Ransikarbum (2021) have used the simulation model that integrates fire dynamics simulation coupled with agent-based evacuation simulation to evaluate the impact of smoke and visibility from fire on evacuee behavior. Ransikarbum (2020) have used the agent-based simulation software to evaluate traffic problems at the intersection. Huihui et al. (2016) have used the Flexsim simulation to realize the storage for a simulation of the operation process and find out the bottleneck existing in the system according to the simulation results, finally, the bottleneck problem to optimize the model, and put forward improvement opinions and suggestions. Darayi et al. (2013) have used the simulation model to study the capacity enhancement scenarios in a tire manufacturing company located in Iran. Samattapapong (2017) have used the model to increase efficiency in the warehouse operation. The result for simulation analysis found that the conveyor belt was a bottleneck in the warehouse operation. Therefore, many scenarios to improve that problem were generated and testing through simulation analysis process. The result showed that an average queuing time was reduced from 89.8% to 48.7% and the ability in transporting the product increased from 10.2% to 50.9%. Thus, it can be stated that this is the test method for increasing efficiency in the warehouse operation. Nie and Wang (2019) have used the Flexsim simulation to improve the operation efficiency of rail mounted gantry crane and reduce the waiting time of container trains and trucks. Ishak et al. (2020) have used the simulation model to find out whether the vise production process time with the number of production targets can be met and is effective. In addition, He and Hua (2018) have established a model of the enterprise operating system to measure the service capabilities of the enterprise through the simulation of the model.

Computer-based simulation has been used increasingly in collaboration with lean manufacturing techniques to manage the number of employees in the production line and to optimize production processes. For example, Chandrakumar et al. (2016) used Flexsim® simulation software and a lean manufacturing system to improve the transfer process's performance. The issues have been identified, particularly wait time, line length, and employee idle time. Kumar et al. (2015) have used the Flexsim for measuring and analysis of performance measures of Flexible manufacturing system is applied. And it has been found that the simulation techniques are easy to analyze the complex flexible manufacturing system. Jarernram (2017) used Flexsim® simulation software to optimize production scheduling and discover the best appropriate overall production time for this issue. Furthermore, the issue was NP-Hard, which meant that finding a solution required a lengthy time. As the complexity of the issue became larger, it required exponentially longer to come up with a solution. The findings demonstrated that simulation techniques may be used to solve difficult and time- consuming issues. Luscinski and Ivanov (2020) have used the simulation model to developed flexible manufacturing system, then the example data were used to demonstrate the developed model applicability. "The Ontology on Flexibility" was applied for evaluation of achieved flexibility of manufacturing system.

Furthermore, Pawlak (2008) have proposes a new modelling framework for simulating flows of people between suburban areas and the metropolis. The model is based on a logit relationship used in researches of transport mode choice problems. Rodalwski (2006) presented the issue of building a model that reflects the real business process, as well as simulating the behavior of that model in order to draw conclusions about effectiveness and efficiency of a real business process. Cárdenas et al. (2018) have used the model to management of a high circulation road connecting two mainstream cities in Chile. Dobrzyński and Waszczur (2018) have used the model to show the opportunities of the analysis of the process according to the scenarios and variants developed in connection with the qualitative assessment process. Kluska (2021) presented mechanism is the basis for the methodology of automatic simulation modeling of warehouses. It allows significant reduction in simulation models building duration, and thus a significant reduction in the time of projects consisting in verifying the concept of spatial arrangement in various projects related to the storage area. The proposed tool is innovative and useful for practitioners specializing in simulation modeling and specialists in warehouse design. Due to the organization and simplification of data structures, it can be implemented in various simulation modeling environments. Also after implementation, it can be used by people who do not have advanced simulation skills.

4 Methodology

This research is a study of the carton manufacturing process A-01 of a case study: an establishment in the packaging carton manufacturing industry. The methods for conducting research were as follows:

(1) Studying the current situation to collect information by studying the procedures, working methods, factory planning, machine position, production aids, and the number of staff. The rule of 3 GEN was applied to explore the real workplace, actual production, and real situation.
(2) Analyzing the information gathered in the first phase and then developing a model for the current situation.
(3) Creating three alternatives and the model of each alternative.
(4) Proposing the most suitable approach to improvement.

4.1 Information About the Current System

The production of paper boxes A-01, the steps are shown in Fig. 1. The first step is putting the raw materials into the paper cutter machine to get the required size. After that, take the cutting pieces to the machine and run them to create an outline that will be simple to fold into a box. The pieces will be checked again for evaluating their completeness and they will be separated into three groups. The first group is unfixable pieces; these products will be discarded. The second group is incomplete workpieces: they will be repaired. And the last group is complete workpieces: they can be formed and packaged into boxes then put into bags, 5 boxes per bag, which can then be kept in a warehouse. The total number of employees is 6, divided into six section (1 employee per section) that include working on a forklift to transport and store raw materials or products that must be sent to customers, paper cutting machine, creasing machine, slotting machine, box forming and packing, and storing.

Analysis of current operational data

From the analysis of the current operation, a large number of pieces in the waiting line had occurred because there was only one staff in the process of forming the boxes and adding foam into the box before delivering to the packing process which was a time consumer. As a consequence, production process was delayed, and employees who were in charge of keeping products faced waiting times. Furthermore, it was discovered that the inspection station for cutting was located at the back of the factory, causing unnecessary transportation, resulting in time wasted on transportation.

Hypothesis

Option 1: Increase the number of employees from one to two for folding and packing the boxes. To reduce the waiting time for the piece, each piece of work that comes out would be completed by the work of one person.

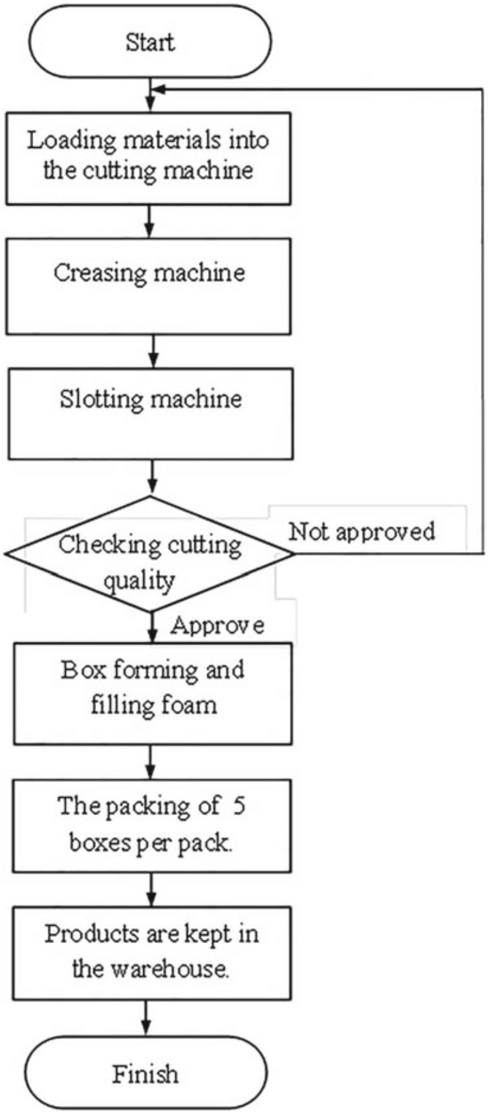


Fig. 1 A-01 carton manufacturing process

Option 2: Increase the number of employees from one to two. The first employee is responsible for folding, while the second employee is responsible for packing. The employees were assigned to do different tasks to be more proficient at that task. Therefore, the employee could work faster and the work would be completed more quickly.

Option 3: Modify the factory layout by relocating the checkpoints that would be kept closer to the paper cutter machine. Then, the storage station would be closer to the

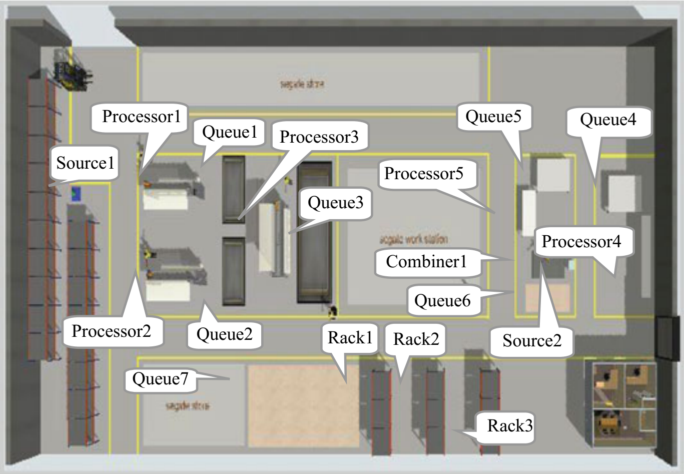


Fig. 2 System representative of the system in the simulation (Top View)

packing station. Thus, it would reduce transportation time and increase the number of products.

Modeling

The modeling processes are the steps to perform various tasks. It can modify the situation to try out new operating systems and it does not cause any impact on the actual operation. It uses computer systems to model and generate alternatives in order to test the most efficient process. Researchers utilized the Flexsim® software, which uses real-life data, to build a current functioning model and alternatives. The following information was utilized in the model's design which was represented in Fig. 2:

1. Source1 represents the arrival of raw materials into the production process.
2. Processor1 represents the paper cutter that cut the raw material to the specified size.
3. Queue1 represents the waiting of pieces before moving to the creasing machine.
4. Processor2 represents the creasing machine. It is used to make a mark which can be easy to form into a box.
5. Queue2 represents the waiting of pieces before moving to the slotting machine.
6. Processor3 represents the paper slotting machine. This will cut the paper into grooves at the specified points.
7. Queue3, Queue4 represent the waiting of pieces before moving to the check-point.
8. Processor4 represents the checking area for evaluating cutting quality.
9. Queue5 represents the paper-forming line.
10. Processor5 represents the area of forming the paper into a box and filling the foam into the box.

11. Combiner1 represents the packing of 5 boxes per pack.
12. Source2 represents the materials that will be used for packing 5 boxes.
13. Queue6 represents the area of the waiting of items before packing.
14. Queue7 represents the area of the warehouse before delivering to customers (Fig. 2).

Verification and validation

Verification is concerned with building the model correctly, according to the conceptual model and its assumptions.

Chi-Square Test for the relationship between the two variables from the number of boxes produced each day from 30 days of data collection of the current system and the generated model to verify that the generated model can be representative of the system.

Figures 4 and 5 show that the generated model can be used to represent the system.

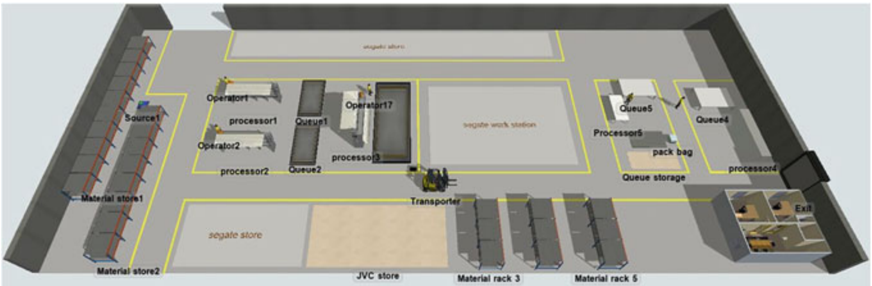


Fig. 3 System representative of the system in the simulation (Perspective View)

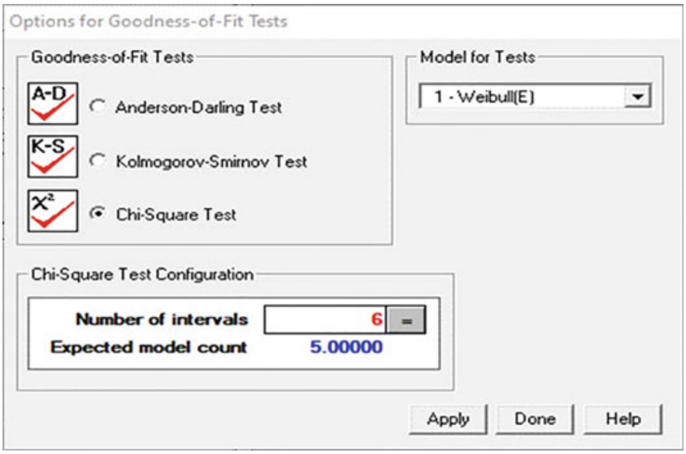
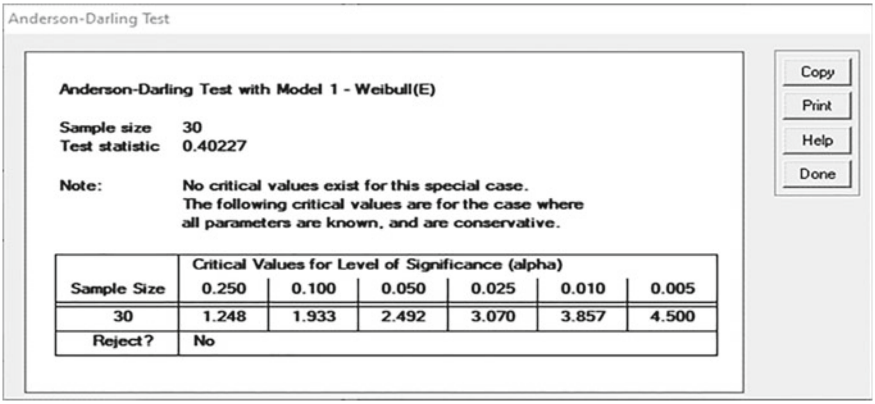


Fig. 4 Using Experfit in FlexSim for Chi-Square Test



Anderson-Darling Test

Anderson-Darling Test with Model 1 - Weibull(E)

Sample size 30
Test statistic 0.40227

Note: No critical values exist for this special case. The following critical values are for the case where all parameters are known, and are conservative.

Sample Size	Critical Values for Level of Significance (alpha)					
	0.250	0.100	0.050	0.025	0.010	0.005
30	1.248	1.933	2.492	3.070	3.857	4.500
Reject?	No					

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Fig. 5 Take the data obtained from the model when running 30 times and validate all 30 results, and the result is not reject

Generate Alternative Model

According to the results of the research of the working process using the Flexsim® software to build a model, the issue arose during the forming and packaging process because there were numerous waiting lines. There were three different alternatives to enhance it:

Option 1: Increase production capacity by adding one person to the box folding and packing station, which would reduce the waiting time of the prior stage (shown in Figs. 6 and 7).

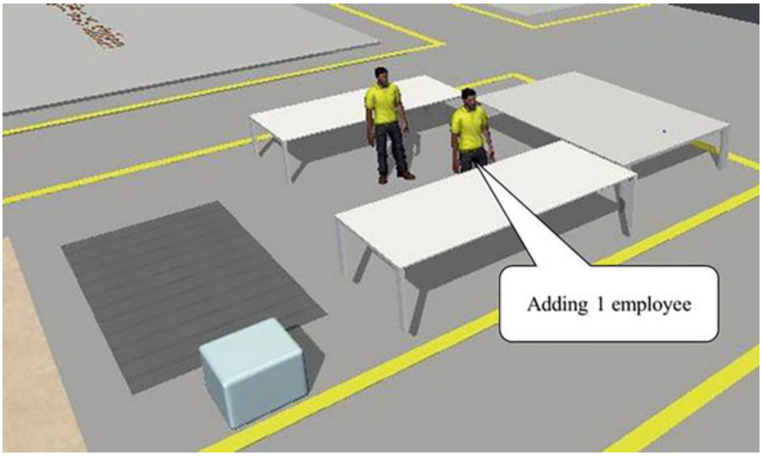

Fig. 6 Adding one employee for option 1

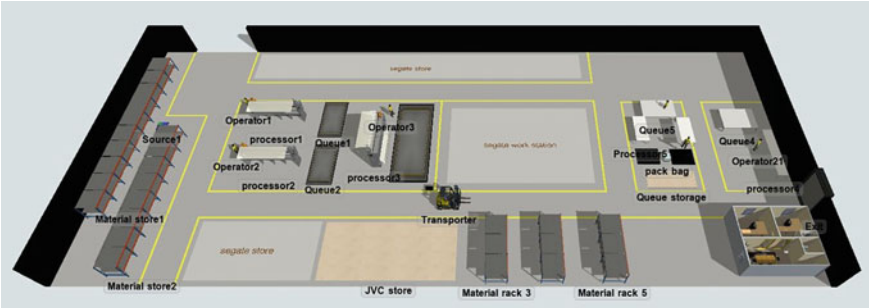

Fig. 7 System representative of the system in option 1

Fig. 8 Adding one employee in packing process for option 2

Option 2: Increase the number of employees in the packing area by enabling current employees to fold the boxes. It allowed workers to work more quickly. (As shown in Figs. 8 and 9).
Option 3: Change the layout of the factory by relocating the intersection check point to the storage site, the workpiece's transit distance was reduced (Shown as Figs. 10 and 11).

5 Results and Discussion

From the experiment using the Flexsim®, the test was run for 28,800 seconds that is 8 hours with the following results: in the traditional system, an average of 701 jobs was submitted, but only 530 were completed, meaning that 74.96% of the total number of jobs was completed and 177 jobs were still being processed (Table 1).

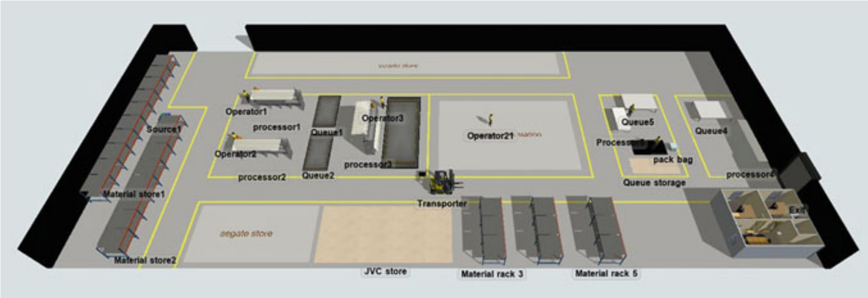

Fig. 9 System representative of the system in option 2

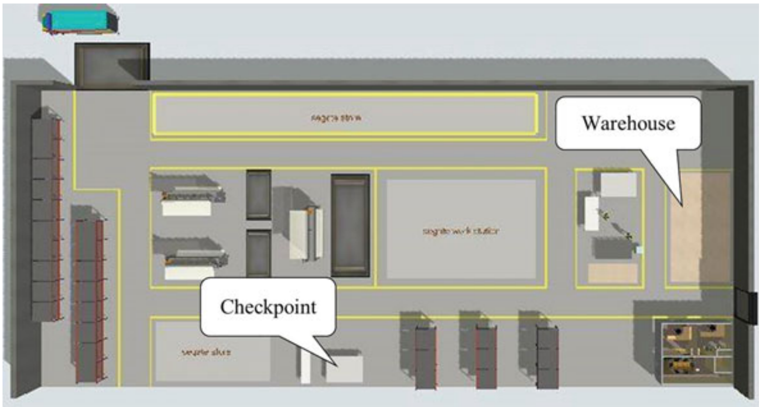

Fig. 10 Factory layout adjustment for option 3

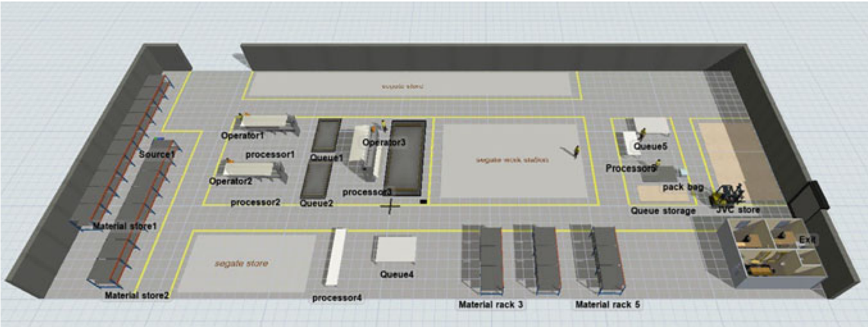

Fig. 11 System representative of the system in option 3

Table 1 Results from the experiment with various scenarios using Flexsim® (tested for 28,800 seconds)

Option	Status			
	Pieces from Source1	Pieces move to Queue7	Work capacity	Work in process
Current system	707	530	74.96%	177
Option 1	701	605	86.31%	96
Option 2	681	585	85.90%	96
Option 3	719	555	77.19%	164

Source Own work

Option 1 (adding 1 person to the forming and packaging unit) resulted in an increase of 11.35% in the number of jobs from the current system to 86.31%. Furthermore, there were 96 items of work in process, down from 45.76% at the present time (shown in Table 1). For the option 2 (one employee in packing process and one employee in forming process), this resulted in the number of jobs accounting for 85.90%, an increase of 10.94% from the current system, and 96 pieces of work in progress, or a 45.76% decrease from the current status (as shown in Table 1). The last option is to change the factory layout, which resulted in the current scenario in which the number of jobs accounted for 77.19% and there were 2.23% more jobs than before, with 164 in-process work items, which was 7.34% fewer than the normal system (shown in Table 1).

6 Conclusions

The findings of this study on simulation and comparing work productivity and waiting time for all three alternatives indicated that option 1 is the most suitable option by adding 1 staff in the forming and packing section. This resulted in the number of jobs representing 86.31% or an increase of 11.35% from the current situation and the work in progress decreased by 45.76%, which is quite similar to the second option. In terms of option 2, the development was planned by adding 1 employee for the packing section. And the remaining staff could work in the folding and forming process. As a consequence, the number of jobs increased by 10.94% from the regular operation, while the work in progress dropped by 45.76% from the regular operation. It was concluded that adding more staff to work in high-waiting areas would help to increase the quality of production and to reduce the wasted time. Therefore, the simulation is used to significantly improve the carton manufacturing process. It can also provide better alternatives, resulting in more effective decision-making, the capability of the process, and competitiveness of enterprises.

The results of this study can be applied to further studies in various aspects, such as modifying the structure of the factory, technology modification, and the appropriate amount of staff and machines for each process. However, choosing the alternative for the improvement also depends on other factors regarding the company's situation. To illustrate, the cost of improvements needs to be suitable with the budget of the company and the number of employees need to be sufficient for the improvement plan. Moreover, the improvement method should not affect the other products of the company. Therefore, it can be concluded that using simulation modeling with Flexsim® provides a clear visualization of the changes without having any impact on the real operation.

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