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PROCESS SIMULATOR FOR MANUAL HANDLING PESTICIDE PACKAGING ASSEMBLY LINE

Siti Norhazlinda Roslan[1], Bulan Abdullah[2*] , Nor Hayati Saad[3], Razali Hassan[4] and Siti Khadijah Alias[5]

[1,2*,3,4] *School of Mechanical Engineering, College of Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*

[5]*School of Mechanical Engineering, College of Engineering, Universiti Teknologi MARA, Kampus Pasir Gudang,81750 Masai, Johor, Malaysia*

[1]snhazlinda@gmail.com, [2*]bulan_abd@uitm.edu.my, [3]norhayatisaad@uitm.edu.my, [4]razalihassan@uitm.edu.my, [5]khadijah_alias@uitm.edu.my

ABSTRACT

Reducing production costs without sacrificing product quality is essential for the global market survival. The problem of line balancing, especially assembly line balancing, plays an important role for industry in achieving the highest quality and lowest cost. This project presents the simulation of line balancing the pesticide packaging assembly line in pesticide-based company. This study aims to develop a productive and effective way of assembling the product to meet customer demands. Line balancing is about arranging a production line so that the production flow from one workstation to the next is even. Line balancing also provides a successful tool to reduce bottleneck by balancing the task time of each workstation so that no delays occur, and nobody is overburdened with their work. The whole project contains study of line balancing through theoretical calculation and analysis done in the simulation model. The simulation was performed using the Process Simulator. Process simulator has been used to simulate the layout condition based in precedence diagram. The first step in using Process Simulator is to create a simulation model of a process in the Visio layout. This is accomplished by adding activities, entities, and resources to the Visio layout and then connecting them with arrival and routing connections. Overall simulation result shows that total unit produce for 5 weeks is 12,240 cartons with average time in system 11,293.85 minutes and average time in operation is 2.39 mins. Filling process and manual labelling process shows highest operation percentage. The percentage of blocked items increased before the bottleneck process. The assembly line plays a critical role in enabling the factory to deliver the right quantity and quality on time.

Keywords*: Assembly Lines, Costing, Cycle Time, Line Balancing, Process Simulator.*

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1. Introduction

Company shall manage the production very well in order to obtain maximum production capacity. Therefore, a systematic approach or technique should be introduced known as line balancing technique. It has been proved that these techniques can improve productivity of the

company. The technique of controlling production waste by eliminating the waste is called lean manufacturing. Lean manufacturing also focusses on cost reduction through eliminating unnecessary activity by applying management philosophy which focused on identifying and eliminating waste from each step in the production chain (Al-Asyraf, 2012).
According to the lean idea, one of the main inhibitors of value flow is inflexibility. It is important to reduce inflexibility to shorten lead time, to lower stocks, to quickly respond to changes in demand, and to achieve just in time production (Miscey, 2014)

Minimizing the number of workstations for a given cycle time and minimize cycle time for a given number of workstations was a common objective for assembly line balancing. Simple assembly line balancing problem is based on a set of limiting assumptions. (N. Boysen, 2007)

An efficient assembly packing line can be obtain by collecting data on current process flow and incorporate with appropriate tools such as line balancing concept, Just-In-Time and Lean manufacturing. This tool is covering total manufacturing concept, which is start from planning, inventory control, layout structure, manpower usage and unnecessary waste reduction. (Alrawi, M. A. ,2023).

The key role to ensure that the product was delivered on time with good quality and correct quantity was to concentrate on the assembly line process. The main reason for this project by increasing the efficiency and productivity of the line. Current assembly packing line was not efficient. Distribution of required task was not evenly over the workstation caused some workstation to have low idle time whereas the other workstation has high idle time. There are no appropriate tools to improve the efficiency of the packaging line, and therefore no evidence to show that the current packaging line is efficient or not. In addition, planning schedule has been revised too frequent due to no preliminary data to refer therefore cause shipment to be delayed. The study will concentrate on manufacturer's problem, which is efficiency of assembly line balancing for packaging line. This research will attempt to overcome the problem by maximizing the productivity as well as efficiency. It also involves minimize cycle time and maximizing task time to full utilize each station capability. The study will focus on manual process improving the automation process. The study will use the process simulator as a tool to demonstrate that the current line efficiency and the simulation result have been improved from the first phase to the second and then the third phase of the project.

Based on the study, bottleneck can be obtained to improve line efficiency. Result will help the company to achieve an efficient line, maximum output, minimum lead time, minimum waste and cost and high profitability. The process simulator can also demonstrate that the current layout is efficient or not and can help predict future improvements to obtain the best layout. Reaches the line. The second issue could be a process error when material reaches the line but cannot complete the process cycle due to a material problem. Due to both reasons, material cannot be attached to the product, material is insufficient, and the process line must be stopped.

2. Literature Review

Assembly lines are widely used in many industries, including chemicals, automotive, food, and electronics. Many studies on assembly lines have been conducted, such as increasing assembly efficiency, even distribution of load to workers, using lean production techniques, and balancing the assembly line. As assembly lines allow for low unit price production due to economies of scale, it is critical to distribute tasks evenly to the stations on the line. Therefore, when designing assembly lines, caution should be the top priority.

Line balancing means assigning work to the smallest number of workstations in a line process to equalize workload between these stations and achieve the desired output rates (Gonzales-Rodriguez, D. C. March 7-10, 2022). There are many types of line models: single-model, multi-model, and mixed-model.

Single Model Line is the product assembled in the same line and there is no issue in setup time because the product run in huge capacity or dedicated machine or dedicated line. Normally the order from customer in big amount so that no need to change the machine setting so frequent. It saves time and money due to the line continuous running and normally low rejection rate. (Akshay C Shettigar, H. S. July, 2019).

Mixed Assembly Line is when the line has different models of product in the same line and the workers works on the differences. Different products represent by product A, product B, and product C. This concept needs multitasking worker so that he or she can handle different type of product. The advantage of this model is the setup time could be ignored due to the line was continuous run and compatible with various type of product.

Multi Model Assembly Line is suitable for short term lot-sizing issue due to this concept are compatible for small order for different customers. Each small size of the batch will have setup time due to the line need to be change based on specific model characteristic. This model easy to monitor especially process performance, rejection rate and packaging material because each item was define based on small quantity in PO. Different product represent by product A, product B, and product C.

The main purpose of line balancing is to match production plan with the output rate. This concept may prevent customer delays and build-up of unwanted inventory. However, rebalancing process line too frequent may result often redesign worker's task, require new detailed layout and paperwork, and will temporary effected productivity. Calculate line's cycle time after determining desired output. Cycle time is total time to finished up each process at each station. If the time to complete each task more than cycle time, the station will be a bottleneck (Shifu Xu a, b. ,. , 2023). Line balancing is used to assign every work element by achieve the desired output rate, all precedence requirements are being fulfil with minimum station formed. Total work element time at each workstation equal to cycle time and no station have idle time, thus perfect balanced is achieved.

3. Methodology

Figure 1 shows the research methodology flowchart for this study. Determine type and characteristic of line layout. Without taking consideration of line type, it may affect to the final calculation and simulation.

Line layout was single model assembly layout due to no issue in setup time because of running in big amount. Then precedence diagram has been drawn to show connection for each station and taking into consideration on immediate predecessor's constraints. As follow to Precedence requirements, certain work elements must be done before the next can begin. (Lee J, M. L. , 2016).

From precedence diagram, identify constraint in process line. In other word, determine bottleneck of each station, which process make the line slow. Based on the diagram, calculated cycle time, number of workstation and efficiency. Concurrently, the layout can be transformed into process simulator (Yilmazlara, I. O. , 2020). Compare the data based on theoretical calculation and process simulator. Then next phase of layout can be modified. There will be certain gap during comparing data and getting the best layout. If there is an error, re-do back the theoretical calculation and process simulation until get the best layout and arrangement. In between changing the layout, run simulation to prove that data calculated was not deviate too much with process simulator program.

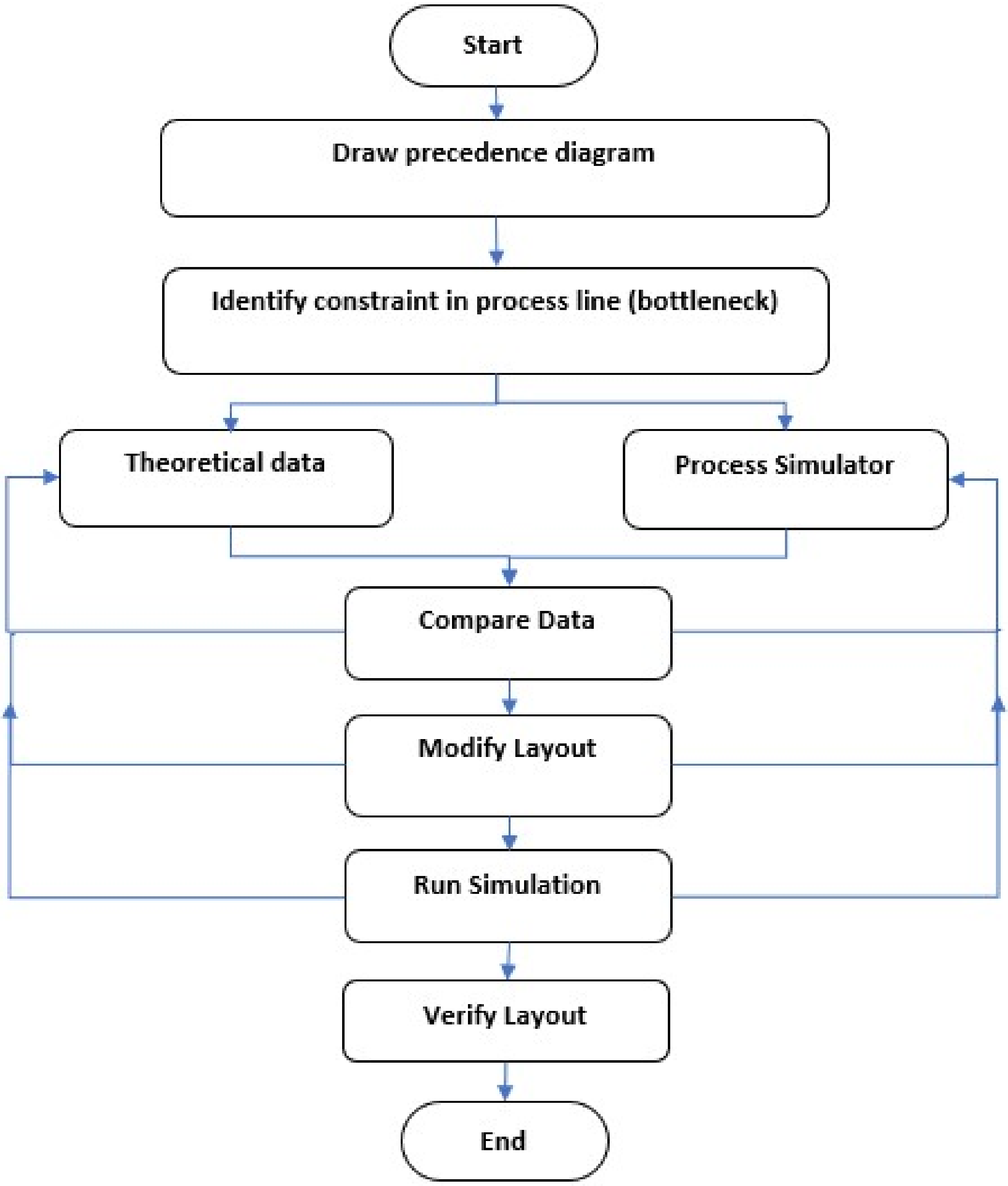

Figure 1. Research Methodoloy Flowchart

Finalize the layout and verify the layout before transforming to the actual line. This avoids high costs in designing and developing the new layout. All results will be discussed, and the best solution will be found to improve the line and reduce the gap. After the process has been completed, a summary and recommendation has been made.

3.1 Contructing Precedence Diagram

Line balancing is to assign equally work to each station in a line process with the smallest number of workstations while achieve the desired output rate. Separate the work into work elements and determine which work that can be performed independently. Each element has their own time standard then identifies which work element need to first before next element can be done; called immediate predecessors (Sotskov, Y. N. ,2023).

First step is drawing a precedence diagram. Precedence diagrams need to be drawn to show a connection between a workstation. To draw the precedence diagram, formulae in (1) until (6) need to be used.

i. Determine the Cycle Time

Cycle time is longest time allowed at each station. This can be expressed by this formula:

$$\textbf{Cycle Time} = \frac{\textbf{Production time available per day}}{\textbf{Units required per day}} \tag{1}$$

ii. To compute the Takt time of the line, the formula below was applied.

$$\textbf{Takt Time} = \frac{\textbf{Total time available}}{\textbf{Total customer demand}} \tag{2}$$

iii. To calculate the minimum number of workstations

$$\textbf{Number of workstation} = \frac{\textbf{Total time for all task}}{\textbf{cycle time}} \tag{3}$$

iv. To calculate the number of workers, the formula is

$$\textbf{Numbers of workers} = \frac{\textbf{Total work content}}{\textbf{Takt Time}} \tag{4}$$

v. To compute the efficiency, the formula is

$$\textbf{Efficiency} = \frac{\sum \textbf{Task time}}{\textbf{number of workstation x largest cycle time}} \tag{5}$$

vi. The productivity of the assembly line also can be calculated by using this formula

$$\textbf{Productivity} = \frac{\textbf{Output}}{\textbf{labor x production time per day (hour)}} \tag{6}$$

Secondly, initiate the data collection process by conducting a time study using a stopwatch, as per theoretical calculations. These work measurement approaches are also applicable to work sampling by using predetermined time standards (PTS) concept. Compare the data taken using stop watch with calculated data using formulae.

Thirdly, identify bottleneck of the process within the entire assembly line.

3.2 Process Simulator Software

A process simulator has been utilized to simulate the layout condition based on a precedence diagram. This is achieved by incorporating activities, entities, and resources into the Visio layout and subsequently linking them together using arrival and routing connections. After that, incorporate additional entities to finalize the model, and subsequently assign attributes to these entities within the model. Afterwards, define the Routing/Arrival Properties and Resource Properties, which should include the cost properties for the resources. The model already incorporates basic logic by defining shape characteristics.

Next, utilize the Logic Builder tool to incorporate sophisticated logic into specific activities related to resource utilization and the manipulation of the work in progress (WIP) variable. Allocate shifts to the resources and specify properties for certain activities in the process. Once all the objects have been defined and the logic has been entered, the layout is prepared for simulating the model to determine if it can successfully reach the goal of producing 40 units per week. After finishing the simulation, users can then access the output statistics. Select "yes" to initiate the launch of the Output Viewer.

Based on the statistics shown in the output viewer, go back to Process Simulator and modify the number of replications in the Simulation Properties dialog from 1 to 20. Re-run the simulation and observe the updated statistics. To accurately represent the process, researchers are able to integrate variability into the model. The model will account for variability for the following areas:

i. Process times at activities.
ii. Arrival quantities.
iii. Resource availability.

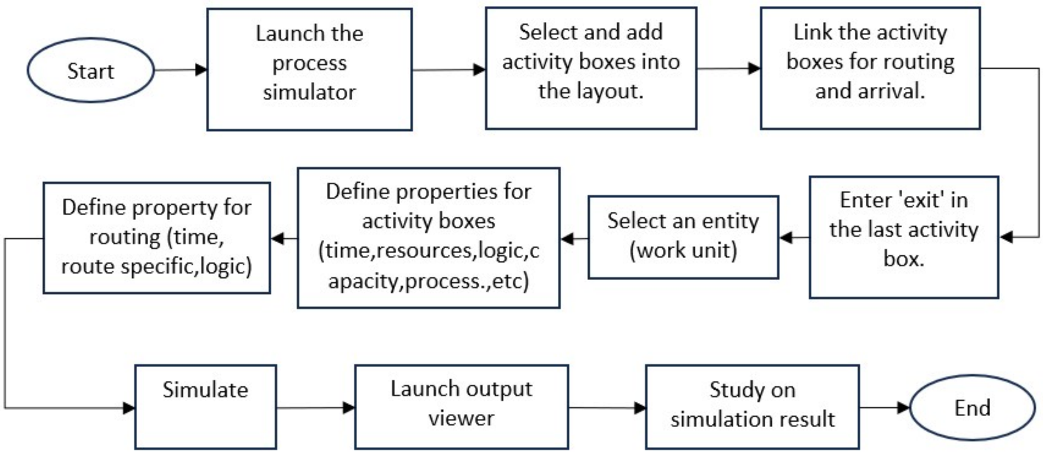

Figure 2. Process Simulator Design Flowchart

4. Result and Diccussion

4.1 Precedence Diagram

Precedence Diagram shown in Table 1 below was Single Model Assembly line which running in huge volume. There are a total of five items produced on this production line. These goods include 4.5L product with a single handle ,4.2L product with a single handle and 2L product with a single handle , 2L product with two handles, and 4.2L product with two handles. The data collection process is only focused on the 4.5L model.

The key difference between various pack sizes depends on the bottle design. Therefore, there will be a duration required for the transition of the product at the filling machine, conveyor, capping machine, and Optical Character Recognition (OCR) machine. However, the elimination of changeover time can be achieved due to the large volume.

The packing process starts with inserting the bottle onto the conveyor, followed by filling of the product into the bottle. The product has predetermined minimum and maximum levels, which are determined by setting the filling machine according to the size of the bottles. If the product goes below or exceeds the specified range, an operator must weigh and adjust the product until it meets at least the minimum level acceptable to the the customer. Then put the insert together with the cap. The bottle will be passed through a capping machine in order to tightly fasten the cap. Upon the labeling process, the batch number printed on the label was verified for readability using Optical Character Recognition (OCR) technology. Each bottle will be packed inside the carton, with 4 bottles in each carton. Next, the carton is weighed using a weighing scale to verify its accuracy. An operator use a carton lifter to systematically stack items onto a pallet, ensuring that each pallet adheres to a predetermined height requirement.

Table 1. Precedence Diagram of Single Model Assembly line fro 4.5L bottle.

Work Element	Description	Task Time (second)	Immediate Predecessors	Process Type
A	Bottle Feeding	1.57	None	Manual
B	Filling	10.45	A	Auto
C	Insert Straw and Plug	4.65	C	Manual
D	Cap tightening	2.43	D	Auto
E	Manual labelling	14.71	E	Manual
F	OCR + Weight Checker	4.1	F	Auto
G	QC check + Cartooning	5.49	G	Manual
H	Check packed gross weight	4.5	H	Manual
I	Palettizing	2.19	I	Semi Auto
Total		50.09		

Precedence diagram presented in Table 1 indicates that both the filling process and manual labelling process for 4.5L bottle have a significant cycle time, with the filling process taking 10.45 seconds and the manual labelling process taking 14.71 seconds. These two operations were the main constraint for the entire line layout. These resulting following processes of bottleneck bottleneck processes experience starvation as their cycle time is less than the preceding phase, causing them to remain idle while waiting for materials or work in progress (WIP). An imbalance in the production line, induced by an uneven cycle duration, resulted in wasted time owing to waiting and unsatisfactory throughput levels at maximum level.

4.2 Process Simulator Result

Figure 3 illustrates the outcome of converting the process map into a dynamic simulation. The work unit progresses from the bottle feeding activity to the filling activity until all activities are accomplished and out from the 'exit'. Simulator can determine the number of 'exit' events in the system. The visualization below shows a total of 17 exits with an average cycle time (CT) of 32 minutes. Following the completion of the simulation, the entity became stuck during the process of filling and manual labelling. This scenario is also referred to as process blocking. This phenomenon arises when the available space for holding work-in-progress (WIP) or buffer stocks is completely filled, resulting in the production line being stopped until the work-in-progress (WIP) is either cleared or processed. The blue entity exhibits rapid movement initially, but subsequently decelerates over a brief period of time. Total exit refers to the quantity of output that an entity produces.

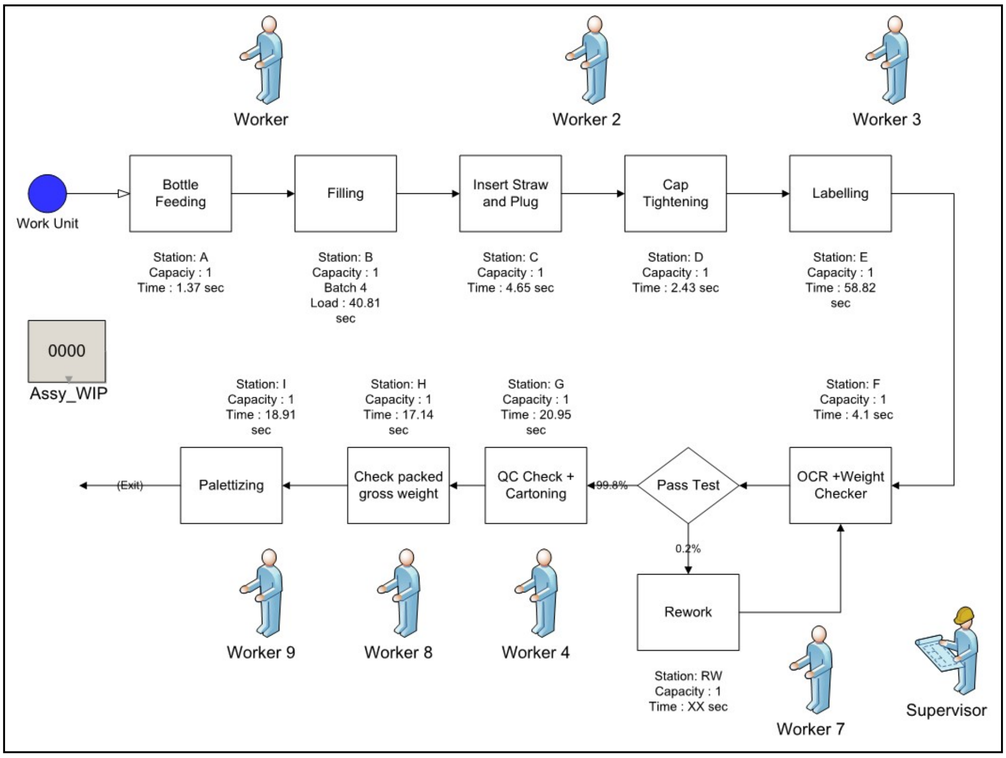

Figure 3. Dynamic Simulation

To obtain the result statistics after completing the experiment, simply run the Output Viewer. Figure 4 displays the results of the analyzing simulation on current assembly line process. The simulation results indicate that a total of 12,240 cartons were over a period of 5 weeks. The average time spent in the system was 11,293.85 minutes, while the average time spent in operation was 2.39 minutes.

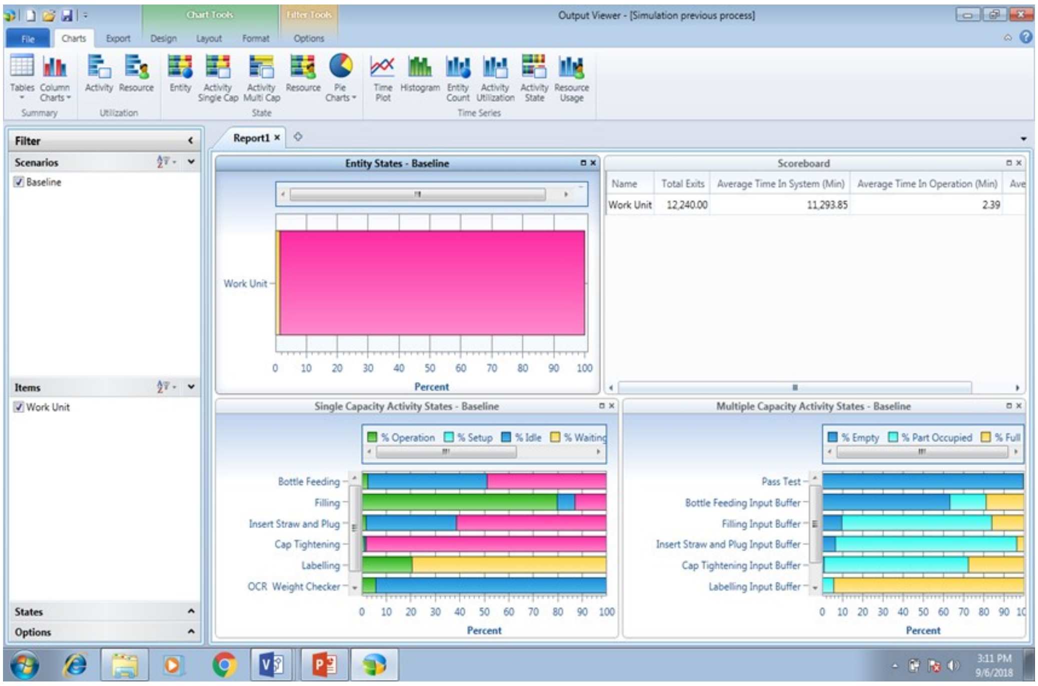

Figure 4. Analysis Simulation Result for Current Assembly Line Process

The simulation of a single activity for the current assembly line analysis, as depicted in Figure 5, indicates a bottleneck occurring prior to the labeling process, as indicated by the pink color. The bottleneck process in this case is the manual labelling process, which means that there is a buffer stock before the manual labelling process. The filling process is the second bottleneck process after the manual labelling process, mostly because the pink color represents the percentage of blockage.The color green represents the percentage of operation in which the work unit succefully completes the cycle and complete the cycle time (CT) is fully achieved.

Figure 5. Analysis Simulation Single Activity

5. Conclusion

In accordance to the precedence diagram and simulation result, research has demonstrated that the manual labelling procedure is a bottleneck. The percentage of blocked items increased prior to the bottleneck process. Therefore, a bottleneck occurred as a result of the manual labeling process that required four individuals to complete. The cycle time of each individual will vary based on their unique skill set, technique, and knowledge. In order to enhance their productivity, each individual in the workforce must undergo multiple training sessions with specific cycle times that must be met. When the manual labeling process becomes a bottleneck, the subsequent processes of OCR (Optical Character Recognition) and weigh checking, including cartooning, also experience process starvation. Process Starvation is the condition in which the subsequent stages after the bottleneck step are forced to freeze or remain passive due to the shortage of materials until the bottleneck process is able to provide materials to the next phase. The simulation results indicate that a total of 11,240 cartons were produced over a period of 5 weeks. The average time spent in the system was 11,293.85 minutes, while the average time spent in operation was 2.39 minutes. The filling process and manual labeling process have the maximum operational efficiency. Similar to other authors who have optimized the process based on simulation (Halim3, 2019), this prediction simulation can assist in predicting the optimal labor and material line configuration so that the line design balances maximum output at lowest cost.

To eliminate bottleneck process and maximize line utilization, it is recommended to transition from manual labeling to an automated process. Switching from manual to fully automated operations may incur higher operational costs initially. However, in the long run, it can lead to increased productivity, less human error, and simplified defect analysis. For instance, while relying on human labor, a particular operation may require the involvement of 5 to 6 individuals in order to achieve the same level of productivity as a single machine. Automation is the optimal method for big production volumes as it results in finished goods that exhibit superior quality, greater precision, and increased productivity (J. B. H. C. Didden, E. L. , 2023). In order to sustain automation, it is necessary to have personnel who possess a high level of expertise to operate the machinery. While automation can decrease the demand for human labor, it still requires experienced personnel to run and oversee the machine.

This research is limited to identifying the specific process that is causing a bottleneck. There are advanced features available, but they require further investment in order to reap more benefits. The Process Simulator allows for the direct export and import of billing models in Microsoft Excel, enabling users to conveniently evaluate and make modifications in a single location before importing them back into Ms Visio. This implies that a highly effective process improvement team has the ability to quickly develop and propose changes, leading to swift enhancements in performance. The improvement team, which is doing a six sigma analysis, can use process simulators that are directly integrated with Minitab. This allows them to perform capability analysis and capability sixpax. Thus, if a precedence diagram has been constructed, the simulation and improvement can encompass the entire cost incurred. By utilizing Process simulator, may further forecast resource needs, optimize capital investments, minimize cycle times, and lower costs.

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Author Contribution

Khadijah Alias prepared the literature review and Bulan Abdullah oversaw the article writing. Norhayati Saad wrote the research methodology and Siti Norhazlinda Roslan performed fieldwork. Razali Hassan conducted the statistical analysis and interpreted the results.

Conflict of Interest

The authors have no conflicts of interest to declare.

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