The effect of quick response manufacturing in factory layout: Assessment using Witness software

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The effect of quick response manufacturing in factory layout: Assessment using Witness software

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Abstract. Nowadays, in a new era of industrial revolution 4.0, there are still many manufacturing companies that tend to neglect the knowledge of optimizing the factory layout. By doing so, the productivity can be increase and lessen the burden of the operator while making sure the quality and also the number of products are also at optimum. The objective of this study is to conduct an analysis on the actual arrangement assembly line using witness software based on QRM in V model assembly and also to propose a new arrangement of the assembly line using Witness software. The data has been collected and recorded through some observation during the visit to X Company. The current layout of the V model assembly line is simulated in the Witness software to get its actual process, percentage of idle, and also the setup time. The software is also used for the new improvement of the assembly line layout to get the comparison for the current layout and after the improvement. Based on the current result, there is some station that has a high percentage of blockage occur in the layout and after the improvement, the percentage of blockage has been reduced which help in increase the production of the model per day. The data that has been recorded from the current is compared with the data after the improvement has been made to the assembly line.

Keywords: Quick Response Manufacturing (QRM); Automotive Industry; Line Balancing.

1. Introduction

As for the automotive industry, it is the industry that covers a wide range of companies involved in the design, development, manufacturing, marketing, and selling of motor vehicles towed vehicles, motorcycles, and also its parts. The automotive industry is one of the most demanding market sectors, in which flexibility and response capability constitute the basis for success [1]. The automotive industry plays a significant role in transforming Malaysia into a more industrial country, which helps to increase economic activities, improved the standard of living of the people as well as higher-paying jobs. As the sector continues to advance, more high-value jobs will be available and these include industrial engineers, technicians as well as product, process, and tool designers. From this statement, the concept of Quick Response Manufacturing (QRM) was introduced. It was first introduced by the late Rajan Suri who was a professor at the University of Wisconsin-Madison at that time in the 1980s. It is quite similar to Lean and also the Theory of Constraints (TOC). The difference between QRM than the other is it emphasizes time or specifically reducing the lead time in a manufacturing process. This strategy helps the company that supplies high variation, less number, and custom-engineered products or parts for customers. For example, Engineer-to-Order (ETO) manufacturers tend to follow the exact time taken for the delivery according to their customers after the order [2]. Time and responsiveness have become strategic factors for the competitiveness of businesses that face the challenge of competing in the dynamic and unpredictable markets of globalized trade [3]. Thus, flexibility and adaptability are vital factors for organizations to respond quickly enough to the demands of twenty-first-century customers, which are primarily characterized by small volume and a high variety of customized products [4, 5].

The importance of reducing lead time was initially recognized in the Toyota Production System (TPS), coined Lean Manufacturing in the occident. For the TPS, non-value added time is one of the seven types of wastes to be removed from production processes in order to maximize customer value and improve efficiency. However, most Lean Manufacturing implementations do not primarily focus directly on lead time reduction but instead on the well-known seven wastes (overproduction, unnecessary transportation, inventory, motion, defects, overprocessing and waiting) which is different from QRM where all of the improvement efforts are directed towards lead time reduction [6]. The POLCA (Paired-cell Overlapping Loops of Cards with Authorization) system implementation [7-9]. In a recent review of the literature on lead time reduction within the context of Time-Based Competition and QRM,[10] noted that currently available literature on practical studies of lead time reduction, particularly QRM, is quite limited.

2. Background

Manufacturing in the automotive industry Increase in societal demand for sustainability has resulted in attention to sustainable manufacturing [11]. Produce vehicles is a big business, but the automotive industry is also a demanding industry for the customer. The industry is made up of companies and workers who manufacture and deliver cars, trucks, and other vehicles to companies that sell them. Companies in the automotive industry fall into one of two primary segments which are car manufacturers and car parts manufacturers. Today’s vehicles are more complex and involve many more parts and electronics compare to past years. These changes lead to an increase in the number of parts and the number of manufacturers.The automotive industry can also improve the economy of the country as there are an increase in jobs and position for people in the industries. At a manufacturing factory, the position that available for them are line workers or operators, supervisors, quality control workers or inspectors, managers, engineers, designers, safety engineers, and executives. Besides, some people provide the routine business operations any organization needs, such as accounting, marketing and advertising, and human resources. On the supplier side, the same types of workers are required. Sales professionals also play an important role in these companies.

2.1 Assembly line

While many people think that Henry Ford invented the automotive assembly line, it was invented by Ransom Eli Olds. Olds had worked on cars for most of his life, including steam-powered cars in the 1880s and 1890s. His assembly line allowed him to be the first mass-producer of cars in the United States, and he dominated the American automotive industry from 1901 to 1904. Assembly line or also known as a progressive line is a manufacturing process where the parts are assembled part by part and from a station to another station sequentially until it becomes a finished product. The line is usually equipped with a conveyor or similar handling system that helps in moving the semi-finished part to another station. Every line has its own cycle time at each station. They need to finish the process according to or below the time given to fulfill the customer’s satisfaction. The product can be done faster with less labor needed by using this process because less number of workers carry the parts. Usually, the assembly line consists of workers, tools, and machines that need to be arranged so that it is easy for the workers to do the operation and at the same time shorten the time taken for the products to be made. There some models of assembly line such as single model assembly line (SMAL), batch model assembly line (BMAL), and mixed-model assembly line (MMAL) which differ according to its product. For automotive industries that produce numbers of identical products, they tend to used SMAL because it is more efficient compare to others.

2.2 Line balancing
The concept of line balancing according to Parvez, et. al is to "design a smooth production flow by allotting processes to workers to allow each worker to complete the allotted workload within a given time [12]. Assembly line balancing is a family of combinatorial optimization problems that have been widely studied in the literature due to its simplicity and industrial applicability [13]. Line balancing is a method where the workload, machines, and also labor are evenly arranged according to the type of work that needs to be done in each work station to ensure that every station can complete the task in the designated time.

It is important to reduce the processing time or buffer, remove any bottlenecks that can occur in the assembly line, and also reduce any worker to overwork. Since the installation of the assembly line is a long-term decision and highly cost-intensive, there is a proper need of designing the assembly line and balancing the workload at the workstations [14]. To calculate for line balancing, firstly we need to have some data for the number of operators, operation, performance, number of products per hour, time to achieve the target, capacity, and also number of the product ordered by the customer.

2.3 Bottleneck process
A bottleneck is a point of congestion in a production system such as an assembly line that occurs when workloads arrive too quickly for the production process to handle. This problem often creates delays in the line and increases the production cost. The manufacturing industry tends to face this problem especially if they produce new products or using a new production line because there may be some flaws from it. The bottleneck may also happen when the demand from the customer is high unexpectedly exceeds the production from the manufacturer. The processor constraints of the bottleneck in the line are defined by the total cycle time in the line. The line capacity is decided by this bottleneck cycle time. Line Capacity is Source of Bottleneck Cycle Time (C / t) and Total Available Time, if Bottleneck C / T < Current Time then demand from the customer has been fulfilled. With the past projected production delivery or from the expected future demand, the takt time is identified for the manufacturing system. With the established takt time, the bottleneck process is defined from the Value Stream Mapping (VSM) and the difference between capacity and demand is determined [15]. For Company X, a bottleneck always happens when there is some model that does not have enough parts such as a seat or its cockpit. If that problem happened, the model is put under Work-in-Project (WIP) as they need to wait for the supplier to send the missing part. The model will still need to be assembled with the available part and go through all the work station before the model is in the store at the end of an assembly line.

2.4 Lead time, cycle time, and takt time
Practitioners and academics are aware of the bad effect of lead times on production and distributions system [16]. Lead time is the time taken between the ordering of products by customers and receiving them back by the manufacturer. Lead-time varies for every company and depends on the products that have been ordered, the number of workers and also the work station and even the location of suppliers for the parts. Lead- time should be considered a variable to be controlled by management rather than a constant. Lead time is important for the satisfaction of the customer as customer want the product as quickly as possible. The shorter the lead time, the more satisfaction the customer gets. The company needs to have accurate forecasting, planning, and schedule on how to reduce it.

Cycle time has various definitions in the literature [17]. The definition of cycle time is the time taken from the beginning of the process until it is finished. Cycle time includes process time for a unit in each work station and also the delay time or buffer which is the waiting time for a unit to move to the next work station. The formula of cycle time is:

$$\text{cycle time} = \frac{\text{Time taken for a unit to produce}}{\text{Number of units required}} \quad (1)$$

Tact time from the German word' taktzeit' means' measure," loop' or' pulse.' This refers to the 1930's march, pacing, and speed control. The Axis Powers collaborated with Germany and Japan. Instead, Japan uses this term to unite during World War 2. This refers to the maximum time required to produce a product to meet the demand of customers. It is important to take time to ensure that all business potential is prepared and used and still meets the overall demand of the customer. This means that the right product is delivered to the consumers in the right amount at the right time. Tact time is a commonly used method within the lean production lines to ensure the most productive flow through each workstation. Take-up time refers to the amount of time needed to produce a product from raw materials to finished products to satisfy customer demand. Tact time will greatly help manufacturing companies achieve higher efficiency. This tool helps in the process to eliminate as much waste as possible.

$$Takt\ time = \frac{Available\ production\ time\ per\ day}{Customer\ demand\ per\ day} \quad (2)$$

2.5 Quick response manufacturing (QRM)

Quick response manufacturing (QRM) is one of the lead time reduction methods that suitable for a company that produces in a low volume but varies in types. QRM is a management concept that focuses on time as the key factor in competitive manufacturing, especially in manufacturing environments for customer-oriented engineering and ordering [18]. A literature review identifies that QRM is based on four concepts which are the power of time, enterprise-wide application, and organization structure and system dynamics.

First, the power of time. Traditionally, the focus of the manufacturing company is on scale and cost management strategies resulting in a high degree of labor specialization and departmental hierarchy. QRM reveals why this conventional system adversely affects lead times and generates a lot of hidden costs. Next, enterprise-wide application. QRM extends time-based management concepts to all aspects of the company, including office activities, inventory scheduling, quality control, supply chain, and new product launch.

For organization structure, QRM provides cells in high mix, low volume, customized environments with principles and tools. They are designed around the Focused Target Market Segment, which is a market segment where shorter lead times provide maximum benefits to the company. They apply to the workplace and office. Lastly, system dynamics. A thorough understanding of system dynamics specifically tailored to high mix conditions complements the cellular structure of QRM. The application of the principles of common process dynamics leads to better capacity planning and optimized batch sizes for short lead times.

It is the difference with lead time as lead time is suitable for a company that produces a higher volume of production but less varies in types or models. While in Make-to-Order environments lean manufacturing can work well, it does only when the demand is very flat and constant. Lean uses a 'pull' System that does not stagnate but produces an additional stock if Lean cannot produce an optimal flow. Lean also uses this system. QRM is different because the monitoring of order flows is done by POLCA (Paired-cell overlapping cards with permission). POLCA is a powerful and simple flow controller that guarantees the speed of orders without any human intervention within the business.

***2.**6 Witness simulation software*

WITNESS Simulation software is a software developed by the Lanner Group Ltd. WITNESS has a simple and interactive interface that enables the users to easily navigate through the simulation. Thompson et al. in their paper states that Witness simulation software is a discrete, systematic occurrence and continuous simulation of processes. This is designed to allow a person who is familiar with the process under study to debug rapidly, incrementally, and accurately. Include complex models and check them. It has a grid interface that displays the toolbar, window modeling, and window structure support. Models are built by using the elements in the model element window tabs.

3. Methodology

This research was conducted in the automotive manufacturing environment located in Malaysia. The methodology of the study is based according to Figure 1. It was started by doing a literature review on QRM, then continue with a tour and internship at the automotive assembly line to learn and learn about the work processes performed by employees while working. This assembly line consists of the Trim Assembly, Mechanical Assembly, and Final of Line Assembly Line. Next, identify the problem during the arrangement of the layout After that, the data from the factory on the assembly line document was collected and the study proceeded to study the selected tools that had already been applied at the automotive manufacturing company X.

The Assembly line situation was analyzed. This research was focused on the factory's low-output assembly line in the V model assembly line number 1. This assembly line has 20 different process stations for each station such as wiring, engraving, and assembly line body preparation station. The overview of methods used to complete the study is generally reviewed in this section. The data was collected here for the simulation. The development of the new model or concept is continued with the Witness simulation program, following the current update to the data. The existing data are analyzed and improved in this section. The setup time is studied and the setup time is improved and improvements are made to the appropriate situation to improve the process.

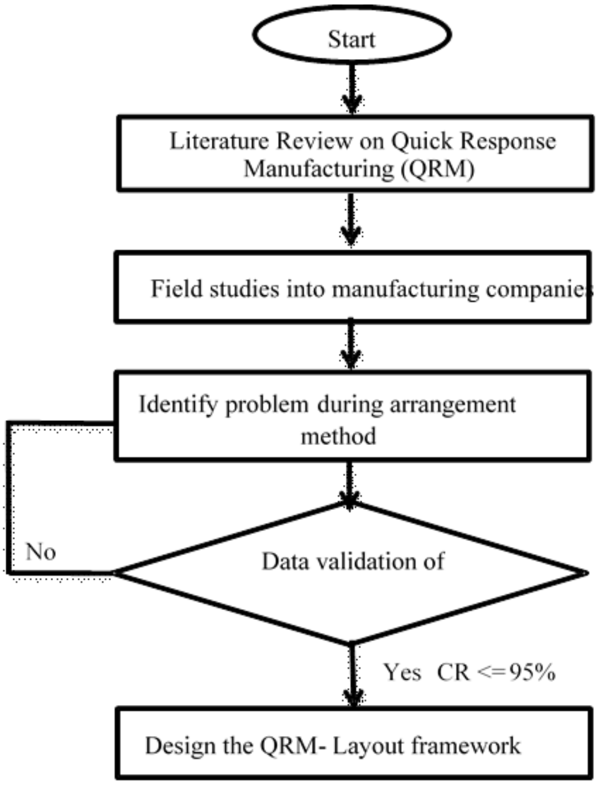


Figure 1. Flow diagram of research methodology.

Data validation is made to get a quality result from the outcome of the simulation. If there is an addition to information or data that is needed for this project, a discussion will be made with the supervisor before going to the company for data collection. The result from both before and after the simulation is recorded and put in the report. The report must be organized according to the requirement to help in understanding it better. The report will be validated by the supervisor before submitting it.

3.1 Data analysis

This research was conducted on company X and focused on just one assembly line that is the V model assembly line. This assembly line consists of 20 workstations and operator numbers with different processes for each station as shown in figure 2. Each station has its number of the operator according to the difficulties of the process. The process that required less work will have less number of operators compared to the heavier work process to reduce any unbalance of manpower in the assembly line. Every assembly line has one person in charge for every three-station which is called multi while the person in charge for the whole line is called PENGHULU. Balancing the number of operators at each station is a must as balancing the line helps in reducing the lead time. It will also remove any buffer in the assembly line. The percentage of blocked parts will also be reduced.

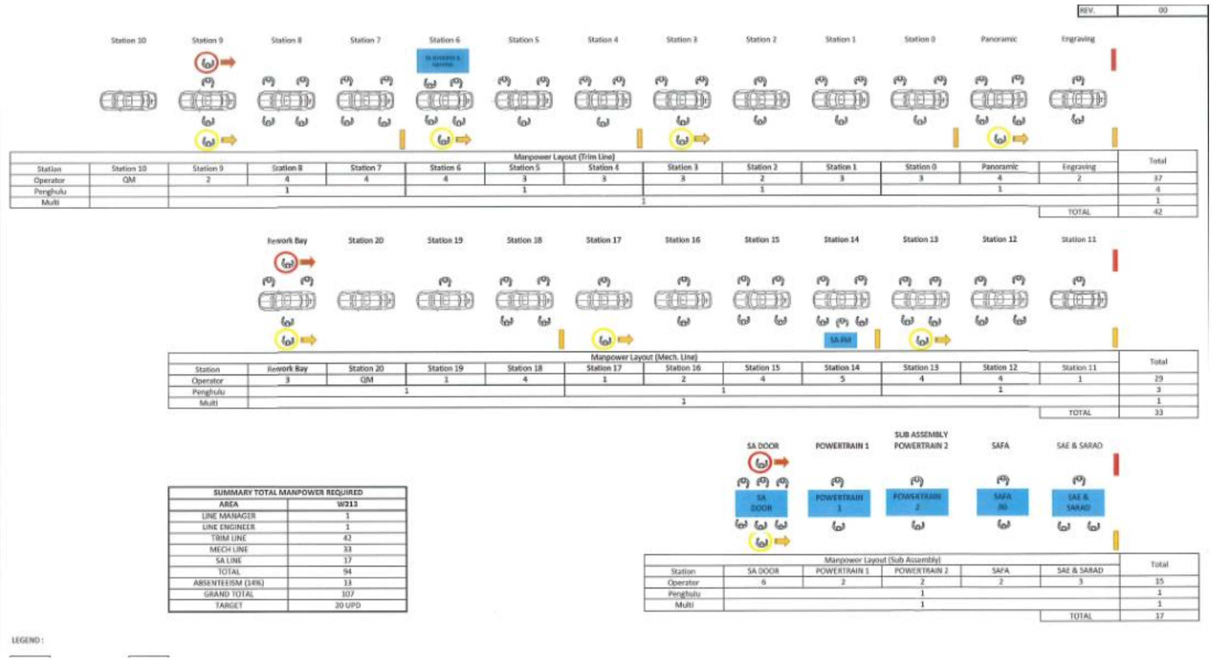


Figure 2. Manpower mapping layout for V Model assembly line.

Each station also had its cycle and tact time. The tact time that the X Company had stated needs to be followed by the operator to get the target output for the day. If there is any station that exceeds the tact time, it will create a buffer as the assembly line is in a single line model. Thus, it will reduce the number of cars produced on that day and increase the lead time of the V model.

From the table 1 shows that a few stations exceed the takt time. Thus, the lead time is also affected. The station that has the problem is the station that we need to tackle to balance it and make sure it is under the takt time. The takt time is had been made by the company to achieve its daily target output. From the current layout, the number of operations or output is 24 units per day. All of the data has been taken during the visit to the assembly line with the help of staff in that company. The collected data will then be used in the simulation to get the initial or current view of the assembly line.

From the data, the takt time as the cycle time for each station in the Witness software. It will be representative of the current layout cycle time. After the analysis, the research begins the improvement of the layout based on the analysis of the current layout.

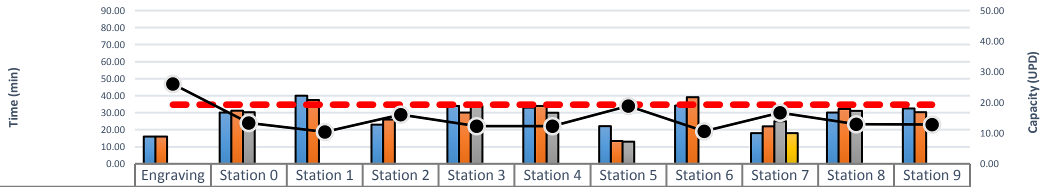
Table 1. Time study for V model assembly line.

Station	Operator A	Operator B	Operator C	Operator D	Highest time	Manpower	Takt time/unit
Door Dissemble/ Engraving	10.00	10.00	-	-	10.00	2	20
Panoramic/ Roof	15.00	15.00	15.00	15.00	15.00	4	20
Station 0	17.00	19.00	-	-	19.00	2	20
Station 1	17.00	16.00	17.50	-	17.50	3	20
Station 2	15.00	15.00	-	-	15.00	2	20
Station 3	23.00	22.00	20.00	22.00	23.00	4	20
Station 4	21.00	19.00	15.00	17.00	21.00	4	20
Station 5	13.00	14.00	13.00	-	14.00	3	20
Station 6	17.00	19.00	18.00	-	19.00	3	20
Station 7	15.00	21.00	20.00	20.00	21.00	4	20
Station 8	20.00	18.00	16.00	-	20.00	3	20
Station 9	20.00	18.00	-	-	20.00	2	20
Station 11 (MER)	4.60	4.6	-	-	4.6	2	20
Station 12 (MER)	20.37	20.37	20.37	20.37	20.37	4	20
Station 13 (MER)	20.91	20.91	20.91	-	20.91	3	20
Station 14	26.20	27.50	25.60	25.60	27.50	4	20
Station 15	24.50	23.70	22.10	22.10	24.50	4	20
Station 16	20.00	19.50	-	-	20.00	2	20
Station 17	22.00	-	-	-	22.00	1	20
Station 18	20.00	22.10	22.10	-	22.10	3	20
Station 19	24.30	-	-	-	24.30	1	20

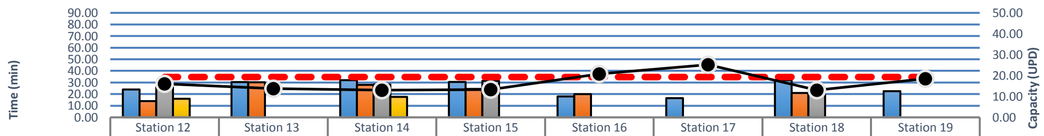
4. Results and discussion

Production productivity is likely to be largely affected by the production line process. Consequently, the assembly line must not be wasteful of action for each process and operation, since the production output is carried out every minute. The current configuration of the V model line is examined to obtain more data on the process setup and to obtain essential data for increasing process and flow, such as cycle time.

The exchanges that take place between the mechanic line and the trim line play a major role in the productivity output that has been wasted as much time there. X company has 3 lines each with different models of car. In this study, we only focused on line 1 or V model assembly line. The improvement is needed to be done to this line to increase the productivity of X company. The arrangement of the layout is important in the improvement.



	Engraving	Station 0	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7	Station 8	Station 9
Operator A	16.00	30.10	40.00	23.00	34.00	33.00	22.10	34.20	18.00	30.10	32.50
Operator B	16.00	31.20	37.50	26.00	30.10	34.00	13.40	39.10	22.00	32.20	30.30
Operator C	0.00	30.30	0.00	0.00	34.00	30.00	13.00	0.00	25.00	31.10	0.00
Operator D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.00		0.00
Operator E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Takt time/unit (12upd)	34.71	34.71	34.71	34.71	34.71	34.71	34.71	34.71	34.71	34.71	34.71
Capacity (unit/day)	26.03	13.35	10.41	16.02	12.25	12.25	18.85	10.65	16.66	12.93	12.82



	Station 12	Station 13	Station 14	Station 15	Station 16	Station 17	Station 18	Station 19
Operator A	24.00	30.40	32.00	30.50	18.00	16.53	32.00	22.53
Operator B	14.00	30.20	28.00	24.50	20.00	0.00	21.00	0.00
Operator C	26.00	0.00	28.32	31.40	0.00	0.00	20.00	0.00
Operator D	16.00	0.00	17.62	0.00	0.00	0.00	0.00	0.00
Operator E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Takt time/unit (12upd)	34.71	34.71	34.71	34.71	34.71	34.71	34.71	34.71
Capacity (unit/day)	16.02	13.70	13.02	13.26	20.83	25.20	13.02	18.49

Figure 3. Cycle time V Model before improvement.

From Figure 3 shows that some station has exceeded its takt time which will affect the production output at the end. Each station has its required task and the task of assembling part is depending on the machine at the station and the number of operators allocated for every station. This data was taken when the manpower well training at every station. Figure 4 shows that the current layout using Witness Software. 20 stations arranged in a line and there was a different number of labor's in each station according to the task, process, and machine use. Each operator is responsible for finishing the required task during the process. Each operator must complete the process at all stations under takt time which is 20 minutes. It is different between the trim line and the mechanical line. Trim needed less time as it was only involved in wiring and small part while a mechanical line is where all the important or big components are assembled. The company was set all stations to be the same as some stations required conveyor and some stations are not. So, to avoid any restrictions or further blockage occur, they decide to sync all stations with maximum tact time which is 20 minutes. From the simulation, the situation of the assembly includes the percentage blocked, the percentage of busy and idle, and also the number of operations or output.

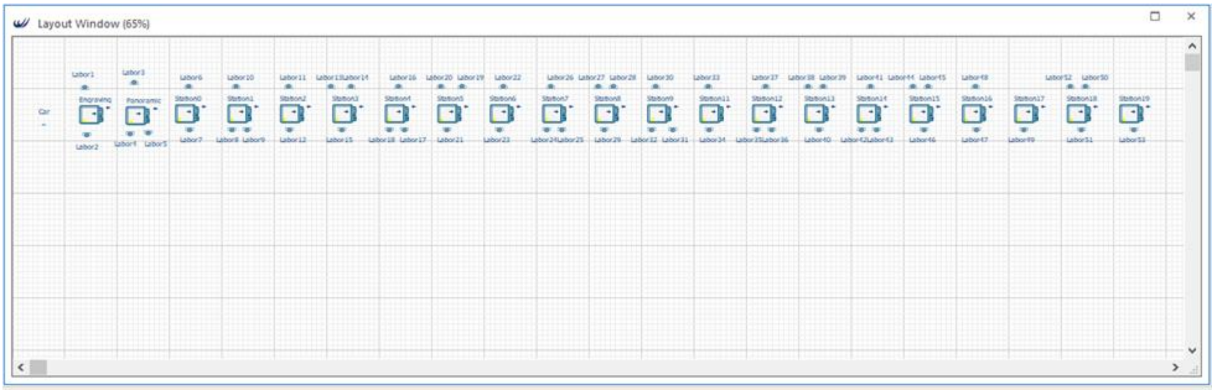


Figure 4. Layout before improvement and cycle time.

Table 2. Machine statistic for V Model.

Name	% Idle	% Busy	% Filling	% Emptying	% Blocked	% Cycle Wait Labor	% Setup	% Setup Wait Labor	% Broken Down	% Repair Wait Labor	No. Of Operations
STN ENGR	0	100	0	0	0	0	0	0	0	0	24
STN00	0	100	0	0	0	0	0	0	0	0	24
STN ROOF	0	100	0	0	0	0	0	0	0	0	24
STN01	0	100	0	0	0	0	0	0	0	0	24
STN02	0	100	0	0	0	0	0	0	0	0	24
STN03	0	100	0	0	0	0	0	0	0	0	24
STN04	0	100	0	0	0	0	0	0	0	0	24
STN05	0	100	0	0	0	0	0	0	0	0	24
STN06	0	100	0	0	0	0	0	0	0	0	24
STN07	0	100	0	0	0	0	0	0	0	0	24
STN08	0	100	0	0	0	0	0	0	0	0	24
STN09	0	100	0	0	0	0	0	0	0	0	24
STN10	0	100	0	0	0	0	0	0	0	0	24
STN11	0	100	0	0	0	0	0	0	0	0	24
STN12	0	100	0	0	0	0	0	0	0	0	24
STN13	0	100	0	0	0	0	0	0	0	0	24
STN14	0	100	0	0	0	0	0	0	0	0	24
STN15	0	100	0	0	0	0	0	0	0	0	24
STN16	0	100	0	0	0	0	0	0	0	0	24
STN17	0	100	0	0	0	0	0	0	0	0	24
STN18	0	100	0	0	0	0	0	0	0	0	24
STN19	11.18	75	0	0	0	0	0	0	0	0	24

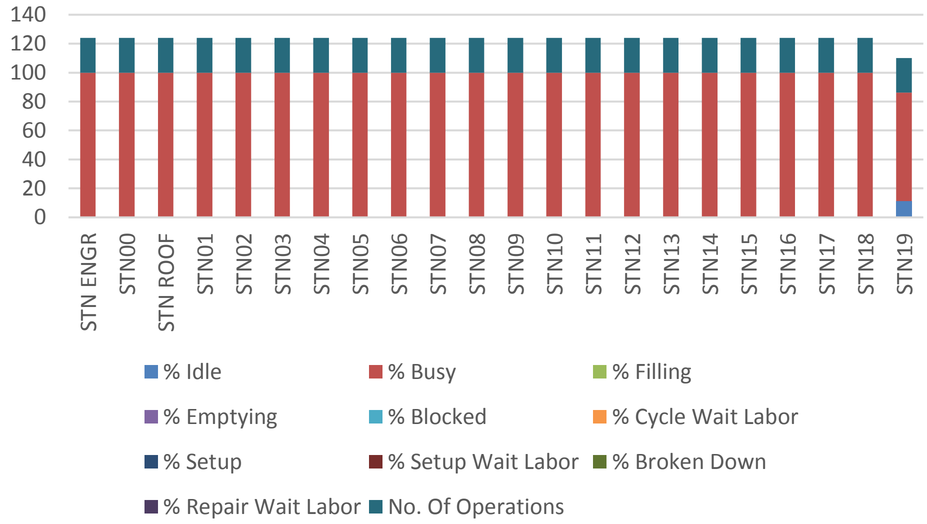


Figure 5. Graph percentage of machine for the current layout.

From Table 2 and Figure 5, it shows that the percentage of busy and idle of the manpower and also the machine in the current layout at the V model assembly line. In this current layout, each operator is responsible for their task. The operator does not do the work for another station. Station 19 has 75% busy while the other has 100%. Station 19 is also the only station that recorded the percentage of idle which is 25% while the others are null.

4.1 Improvement with added buffer area

To reduce the time of the operation can be made. Reviewed and then make a changed or alteration in the mechanism by which the system has been reordered, as in the new interface was implemented. With each station, the process changed and there was a workload imbalance. Therefore, added the buffer area or storage for any parts that finished before the next station took it to continue the assembly process. From the current layout, the percentage idle at station 19 while the others have 0% idle. Moreover, to overcome it by adding or placing a buffer area or storage area between station 9 and station 11 which this station is between the trim line and mechanical line. The number of cars that can be put in the area is 1. By having this area, the percentage of busy is reduced while the percentage of idle is increased for all station.

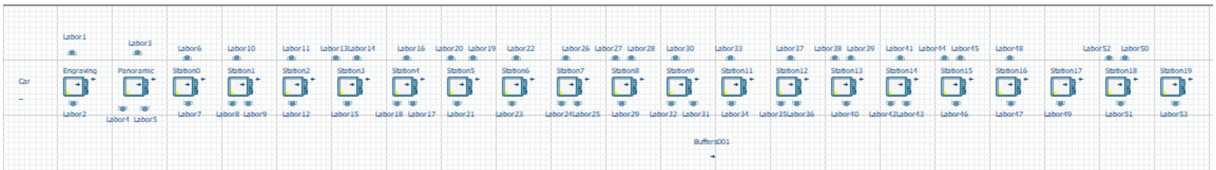


Figure 6. Proposed layout after adding buffer area.

Name	Total In	Total Out	Now In	Max	Min	Avg Size	Avg Time	Avg Delay C	Avg Delay Ti	Min Time	Max Time
Buffers001	23	23	0	1	0	0.05	1.00	0.00	0.00	1.00	1.00

Figure 7. Buffer statistics.

The results, shows that the buffer area will have the same amount of parts for in and out which is 23, and help in reducing the lead time rather than have to wait for the station to finish before transfer it to the next station.

Table 3. Machine statistic after added 1 buffer area.

Name	*% Idle*	*% Busy*	*% Filling*	*% Emptying*	*% Blocked*	*% Cycle Wait Labor*	*% Setup*	*% Setup Wait Labor*	*% Broken Down*	*% Repair Wait Labor*	*No. Of Operations*
STN ENGR	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN00	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN ROOF	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN01	*1.46*	*98.54*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN02	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN03	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN04	*1.46*	*98.54*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN05	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN06	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN07	*1.46*	*98.54*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN08	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN09	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN11	*1.46*	*98.54*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN12	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN13	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN14	*1.46*	*98.54*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN15	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN16	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN17	*1.46*	*98.54*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN18	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN19	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*

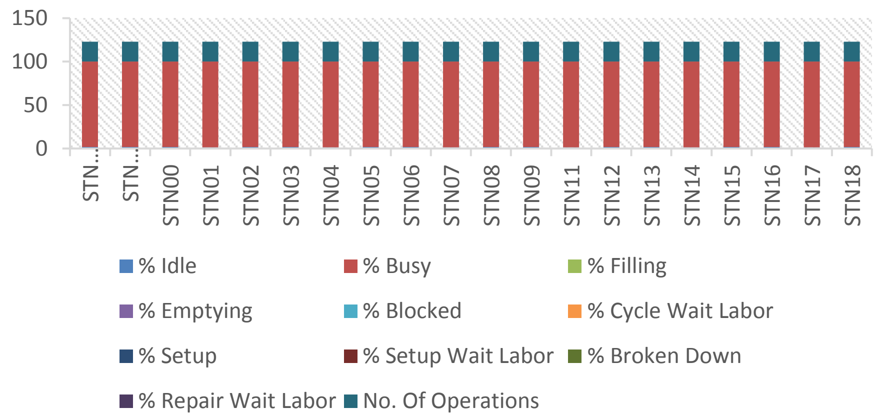


Figure 8. Graph percentage of the machine after adding one buffer.

The simulation to install more number of a buffer area in to improve that the result can help in reducing the percentage of idle and busy while increasing in production. Unfortunately, the result is the same as the previous one. From the simulation, the percentage of idle and busy for each station is the same for install one buffer area or two buffer areas as shown in Table 4 and Figure 9.

Table 4. Machine statistic after added 2 buffer area.

Name	*% Idle*	*% Busy*	*% Filling*	*% Emptying*	*% Blocked*	*% Cycle Wait Labor*	*% Setup*	*% Setup Wait Labor*	*% Broken Down*	*% Repair Wait Labor*	*No. Of Operations*
STN ENGR	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN00	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN ROOF	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN01	*1.46*	*98.54*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN02	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN03	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN04	*1.46*	*98.54*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN05	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN06	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN07	*1.46*	*98.54*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN08	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN09	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN11	*1.46*	*98.54*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN12	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN13	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN14	*1.46*	*98.54*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN15	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN16	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN17	*1.46*	*98.54*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN18	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN19	*1.67*	*98.33*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*

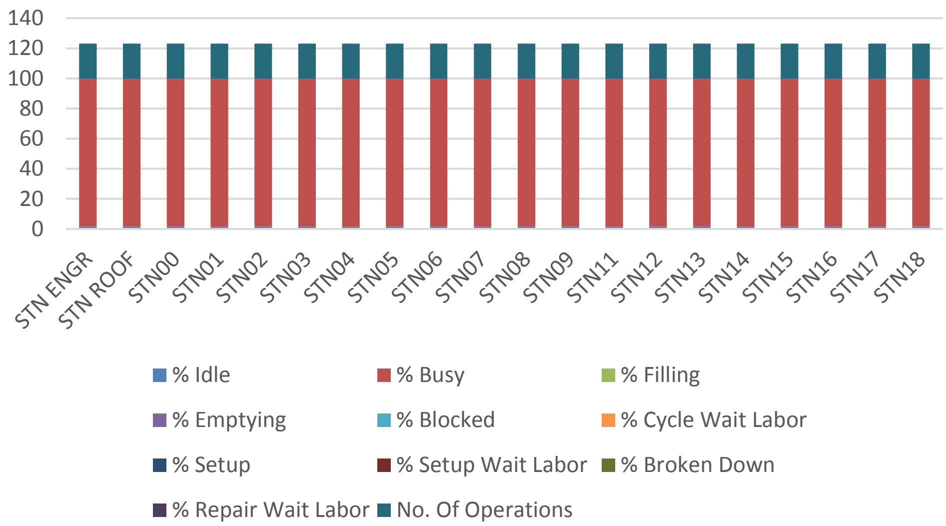


Figure 9. Graph percentage of the machine after adding two buffer.

4.2 Combining station

Moreover, there have proposed another method which is by combining some stations that is suitable according to its process. By combining these stations, this research reduces some buffer time or reducing any time waste as it will avoid any blockage from the previous stations. From this research to combine any station starting from station 11 until station 19 or known as the mechanical line. It is due to its process which involves assembling the components of the car such as the engine, cockpit, and also exhausting. All of this part is big and has its machine that helps in assembling it. So, this research suggests that to combine stations from the trim line which are station door dissemble and engraving with station panoramic or roof. For the door dissemble and engraving station, the labor or worker task is to disassemble the door before the car is a move to the next station to ease the operation. They also need to engrave the chassis number for the car in this station. As for the panoramic or roof station, the operator needs to disassemble the sunroof of the car. The other station that we combine are station 4 and station 5 as the scope of work is quite similar. Both stations involve processes such as assembling the cockpit or dashboard and also installing all the cables or wires around the interior of the car. Two more stations that were combined are station 7 and station 8. The process that involves in that station is assembling the rear window and also installing the rear-view mirror. All the stations as involves in assembling small parts and also do not depend on the process from previous stations. For the stations in the mechanical line, it is quite impossible to combine as there are many big components and huge assembly machines required to use to continue the process.

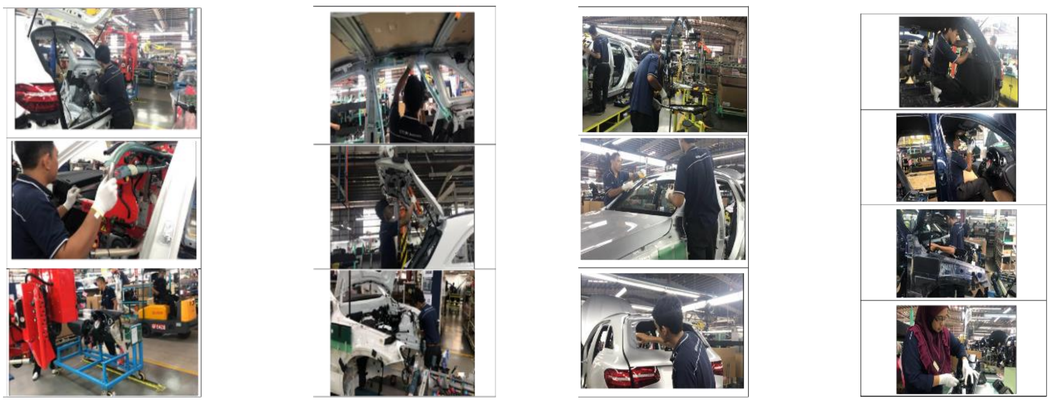


Figure 10. Pictures of station 4, 5, 7 and 8.

Figure 11. Proposed layout after combine station.

Table 5. Machine statistic after combine station.

Name	% Idle	% Busy	% Filling	% Emptying	% Blocked	% Cycle Wait Labor	% Setup	% Setup Wait Labor	% Broken Down	% Repair Wait Labor	No. Of Operations
STN00	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN01	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN02	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN03	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN04 & 05	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN06	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN07 & 08	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN09	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN11	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN12	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN13	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN14	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN15	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23*
STN ENGRV & ROOF	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN16	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN117	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN18	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN19	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN18	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*
STN19	*0*	*100*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*24*

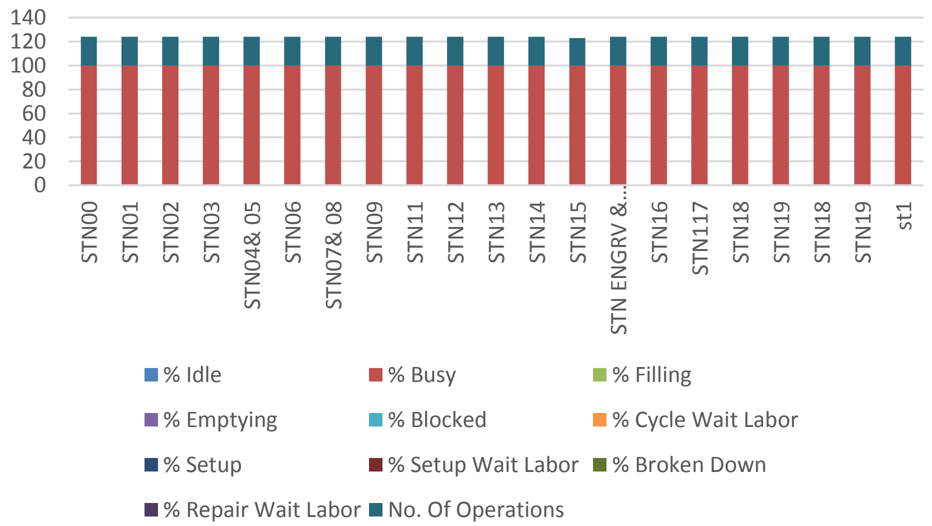


Figure 12. Graph percentage of the machine after combine station.

4.3 Discussion

From the research, as to conclude that the best improvement that can be made is by combining the station compare to adding a buffer area between the trim and mechanical line. The results show and are compared with each other. Combining the station in the trim line is better.

Table 6. Comparison between current, adding buffer and combine layout.

Name	% Idle	% Busy	No. Of Operations
Current	1.190476	98.8095	24
Buffer	1.61	98.39	23
Combine	0	100	24

From the table, adding a buffer area between station 9 and station 11 will not improve its output or percentage of busy. The current output is 24 while after improvement is 23. The percentage of busy is also reduced from 98.8095% to 98.39%. As for the percentage of idle, the current layout will give 1.190476% while adding the buffer area will increase the percentage of idle to 1.61%.

This buffer area is only some suggestion that can be made but cannot be done directly as the factory does not have enough space to provide it. This research needs to consult with the responsible person in the company to execute the process. The current layout of the factory is quite close to another assembly line so it will be difficult to have some space for buffer or storage area between stations.

By combining the station, the production output is constant with 24 units per day but the percentage idle will be eliminated from 1.190476%. The percentage of busy will also increase to 100% of 98.8095%. After combining the selected station, the time for one unit to be assembled is faster compare to the current one. This method will balance the time for all stations so there will be no stations that will have any lead time.

For the current layout,

$$21\ stations\ (20minutes) = 420\frac{minutes}{unit} \tag{3}$$

After combining the station,

$$18\ stations\ (20minutes) = 360\frac{minutes}{unit} \tag{4}$$

According to the QRM method, it is important to reduce the lead time as it will affect the productivity of the company. QRM is a suitable method for this company as this company also supplies high variation and fewer numbers of products for customers. For example, this company has 3 classes of the car with 3 different assembly line but all of the lines only produced below 100 units per day.

The best solution for improvement by combining the stations. Even though the output is still the same and cannot be increasing as the percentage of busy has reached 100%, it still can eliminate the percentage of idle that affected the lead time. After combining the stations, the lead time can be reduced and the time taken for one unit to be producing will be shortened.

5. Conclusion

The objective of this research is to analyses the current layout and also propose a new arrangement of the assembly line by using the Witness software. At first, the simulation of the current layout of the V model assembly line has been set up using Witness software. According to the result that we have from the simulation, station 19 is the most critical area in the line. It is because station 19 does not achieve 100% of busy while another station achieves it. The percentage of idle from station 19 is 25%. We need to reduce the percentage of idle as it will increase the time for production. This extra time is called lead time and we need to reduce it.

This problem brought to the next objective which is to propose a new arrangement of the assembly line. From the current layout, the proposed two new possible arrangement or improvement that can be made by using the Witness software. Firstly, by adding a buffer area or storage between station 9 and station 11 as it is the intersection of the trim and mechanical line but the result does not reach the research expectation. Thus, the output is decreased to 23 units per day from 24 units per day. The next arrangement by combining the stations in the trim line. The results achieved the target by eliminating the percentage of idle in station 19 and make the percentage of busy 100%. Even though the output is still the same, the reduction of the time for one unit to be produced from this improvement. This method was selected as the result is better to compare to the previous one.

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