A Study on Line Balancing in Assembly Line at Automotive Component Manufacturer

M. Mohd Hafizuddin, N.K Ahmad Nazif, Y. Mohd Needza and D. Azila Nadiah
Faculty of Technology
University Malaysia Pahang
26300 Gambang, Kuantan, Pahang, Malaysia

Abstract

Assembly line need to be design properly base on the types of product, workloads required, numbers of daily production as well as others element. The balance assembly line is the line that has high value of line efficiency. The higher output of the line can be considered as the efficient line because more number of products can be produced in the specific production time. Through process observation and time study that been conducted in automotive component manufacturer, the data analysis revealed line balancing efficiency at that company has increased by 16.3% when the layout being redesigned from straight line to U-shape line. The redesign of the line layout has effect some changes in the processing the workpieces where time difference between operators involved reduced from 15.6 second to 6.9 second which means the operators have to perform approximately equal workload. Furthermore, total process cycle time require to completely assembling the product reduced from 133.0 second to 122.3 second equivalent to 8.0% time reduction. The process improvement activity achievement is not only depends on the redesign of the layout but it also involved operators position arrangement, minimize idling time and changing the work sequence.

Keywords
Assembly line, line balancing, line efficiency

1. Introduction
In the modern's era, process efficiency in manufacturing especially in automotive industry is very crucial in dealing with the demand of the customers. Automotive manufacturer need to be more efficient in producing the vehicles so that those vehicles can be delivered to the customers in shorter period of time without having any quality complaint. In order to achieve higher productivity in mass production environments, assembly line concept had been used in most of the company that involved in manufacturing automotive components. In fact, assembly line can be a determinant in measuring the efficiency in the production operation of automotive manufacturer.

Assembly line had evolved several times since the introduction of the first assembly line. The original assembly line was strictly paced and straight single-model lines. Then, the assembly line had evolved by the needs of manufacturing industry. Nowadays, the assembly line becomes more flexible such as the line with parallel work stations or tasks, U-shape line, customer-oriented mixed-model and multi-model lines. Each type of the assembly line is suitable in different production environments depends on type of product, workload requirement and as well as number of quantity produce per day. Each type of the assembly line had it own advantages and disadvantages.

Pyo (2000) stated that the good assembly line is the line that has high value of line efficiency. Line efficiency can be define as the percentage of good parts at the end of the line versus the theoretical number that the line should produce in a given time period. Time periods for averaging are determined by the goal of the production. To achieve 100% line efficiency, one station must never be blocked or starved and the station must always operate at its theoretical capability. The higher outputs of the line can be considered as the efficient line because the line can produce higher outputs in the specific production time.

Line balancing can be define as the process of assigning tasks to workstations in such a way that the workstation have approximately equal time requirement (Stevenson 2002). The tasks that assign to each workstation must fulfill the equal time requirement. In other words, the workloads at each workstations must be the same and the time consume during the assembly process is also equal at each workstations. According to Benzer et al. (2007), the fundamental line balancing problem is how to assign a set of tasks to an ordered set of workstations, such that the precedence relations and some performance measures (minimizing the number of workstation, cycle time and idle time) are satisfied. Hence, Eryuruk et al. (2008) provides two main goals while balancing an assembly line which are minimization of the number of workstations for a given cycle time and minimization of the cycle time for a given number of workstation.

Production department can be gladly satisfied with the assembly line if the line can achieve higher level of line efficiency. The higher the level of efficiency indicate that the line implemented by the company are the best line for the production process and also produce higher outputs in the specific given time. Meanwhile, the line that had lower line efficiency need to be study and troubleshoot to find the causes of the problem. Once the root cause was found, the corrective and improvement action such as redesign the assembly line layout or re-arrange the work sequence must be done. This practice will increase the value of line efficiency and fully optimize the line capacity.

This paper focuses on the line balancing study in one of the automotive component manufacturer company located in Selangor, Malaysia. Data obtained from the observation of the assembly process parallel with the time study. The existing assembly line layout is straight line. Then the company redesigns their assembly line layout to U-shape as part of the process improvement activity. Cycle time for each assemble process for both before and after improvement is taken and been analyzed to get the line efficiency value. From the result, company may compare and identify which type of assembly line suit with their target and provide better performance.

2. Line Layout

2.1 Straight Line (Before Process Improvement Activity)

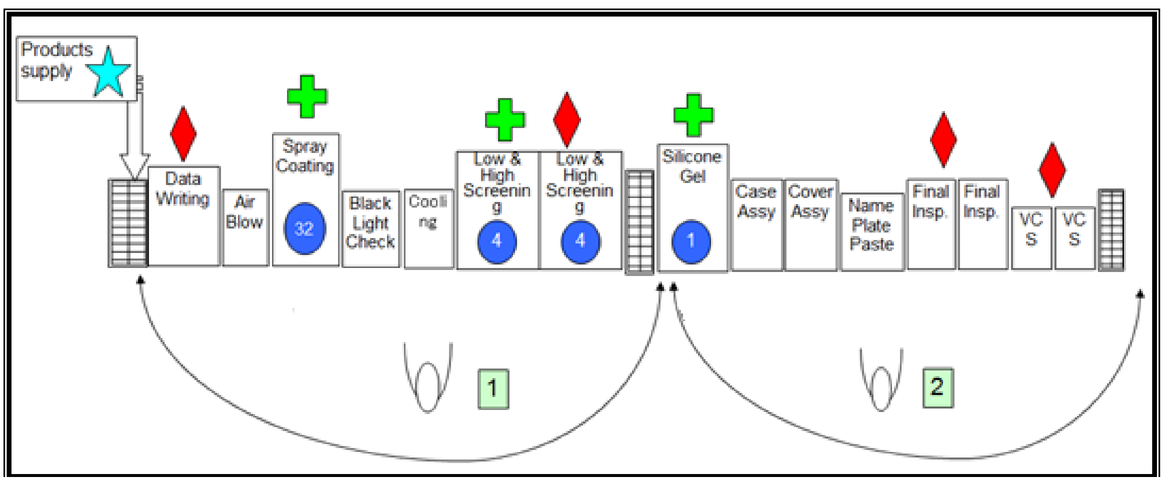

Figure 1: Illustration of straight assembly line layout

Existing type of assembly line that implies at the company is straight line as shown in Figure 1. Along the line, there are 2 operators who are responsible to conduct the task or assemble the workpiece. The operators are working side by side. The workpiece will move along the straight assembly line and the first operator will start doing the assembly task when the workpiece being fed to the first workstation (Betancourt 2007). The task starts with data writing process until the low and high screening process. Then the workpiece will be transfer to the second operator. The second operator starts the task with applying silicone gel until the VCS process. The task completes when the operator conduct quality checking and store the workpiece in the polybox.

2.2 U-Shape (After Process Improvement Activity)

The company conducts process improvement activity at the assembly line. The main reason is to improve the efficiency of the assembly line in order to achieve higher output in the specific time period. Besides that, the mobility of the workstations, cycle time distribution and equal workload between operators are in their concern. The redesign layout is shown in Figure 2. There are 2 operators working at the assembly line. By using this type of layout, it require the first operator to pass the workpiece to the second operator and then the second operator need to pass back the workpiece to the first operator in order to complete the assembly process. Both operators still working side by side but this time they need to move according to U-shape in order to complete the task (Baykasoğlu and Dereli 2009). They need to stand at the middle of two workbenches instead of facing the workbench. The first operator task starts with data writing process and ends up with cooling process. Then, the workpiece will be transfer to the second operator. The second operator task will start with the work at low and high screening process until cover assembly process. Next, the workpiece will be transfer back to the first operator. The first operator will do the name plate paste process until quality checking before store the finish workpiece into the polybox.

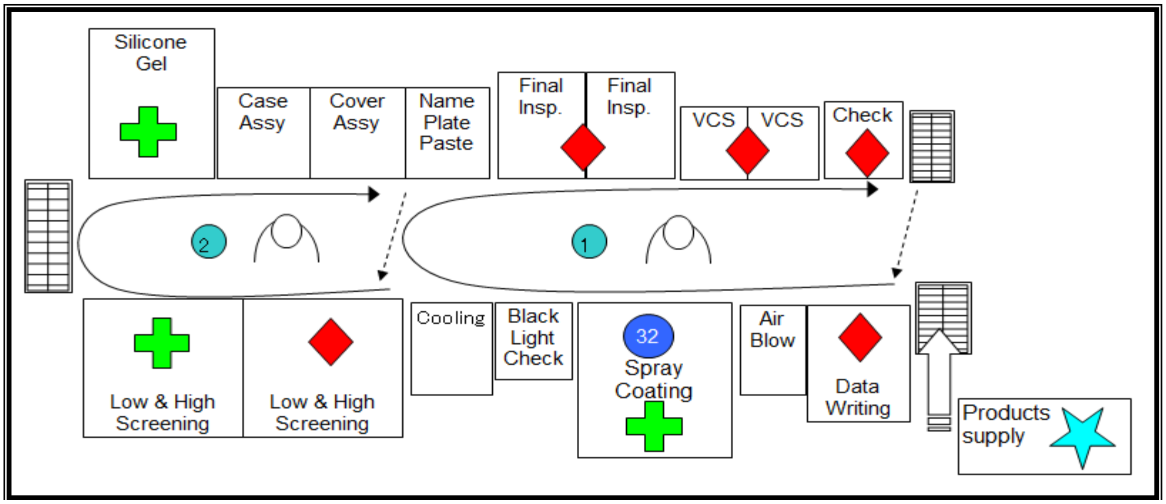

Figure 2: Illustration of U-shape assembly line layout

3. Mathematical Formulation

The line balance loss can be determined in 3 ways which are time, man power and balance efficiency. The equations for determining the line balance loss are stated as below:

$$\text{Time} = (\text{ATT x Number of Associates}) - \sum (\text{H.T} + \text{W.T}) \tag{1}$$

$$\text{Manpower} = \frac{(\text{ATT x Number of Associates}) - \sum (\text{H.T} + \text{W.T})}{\text{TT}} \tag{2}$$

$$\text{Balance Efficiency} = \frac{\sum (\text{H.T} + \text{W.T}) \times 100}{(\text{ATT x Number of Associates})} \tag{3}$$

Where: ATT = Actual Takt Time (in second)
TT = Takt Time (in second)
H.T = Manual Work (in second)
W.T = Walk Time (in second)

4. Results and Discussions

4.1 Work Sequences

Table 1 (a): Elemental work for straight line

Table 1 (b): Elemental work for U-shape line

Sequence	Elemental work
1	Data Writing Process
	Air Blow Process
2	Spray Coating Process
	Black Light Checking
	Cooling Process
3	Low and High Screening Process
	Silicone Gel Process
4	Case Assembly Process
5	Cover Assembly Process
6	Nameplate Pasting
	Final Inspection Process
	VCS Process
	Check and Store into Polybox

Sequence	Elemental work
1	Data Writing Process
	Air Blow Process
2	Spray Coating Process
	Black Light Checking
	Cooling Process
3	Low and High Screening Process
	Low and High Screening Take Out
	Silicone Gel Process
4	Case Assembly Process
5	Cover Assembly Process
6	Nameplate Pasting
	Final Inspection Process
	VCS Process, Check and Store into Polybox

Along the line, there are 6 sequences of work. Each sequence has the own elemental work. The elemental work for each sequences are stated in the tables. Table 1(a) shows the elemental work for the straight line which is the layout before process improvement activity conducted. Meanwhile, Table 1(b) shows the elemental work for the U-shape line that go through redesign process in process improvement activity. There are some differences between the elemental work for the straight line and U-shape line. The differences occur at the work sequence 3 and 6. For the straight line, elemental works for sequence 3 are low and high screening process and silicone gel process. After redesign the layout, there are additional elemental work for the sequences 3 which is low and high screening take out. Meanwhile, there are 4 elemental works of sequence 6 for the straight line which are nameplate pasting, final inspection process, VCS process and check and put into polybox. After redesign the layout, the VCS process and check and put into polybox has combine to become one elemental work.

4.2 Cycle Time Comparison

From table 2, data shows that cycle time of sequence 1 has reduced 9.5% and cycle time for sequence 2 reduced to 13.7%. While cycle time for sequence 3 has reduced 3.0% after redesign layout take place. Data in table 2 also reveal that increasing of the cycle time occur for the sequence 4 and 5. Cycle time at sequence 4 has increase 7.5% and 7.6% at the sequence 5 but sequence 6 shows a huge impact in cycle time differences where it has reduced 34.4%. As overall, total cycle time difference between straight line and U-shape line has reduced 8.0%. It shows that the operators occupy less cycle time for the U-shape line compare to the straight line.

Table 2: Comparison of sequence time

Sequence	Sequence Time (sec)		Time Reduce (%)
	Before (initial)	After (redesign)	
1	19.9	18.0	9.5 %
2	20.4	17.6	13.7 %
3	26.9	26.1	3.0 %
4	18.6	20.0	+ 7.5 %
5	15.8	17.0	+ 7.6 %
6	31.4	20.6	34.4 %

Total	133.0	122.3	8.0 %

4.3 Workload Differences between Operators

From table 3, the workload for operators 1 has reduced 1.7% after the process improvement activity take place. At same time, the workload for operators 2 also reduced to 13.1%. It shows that there is major improvement of the workload for the second operator. The workload occupy had reduce significantly after the redesign layout process. Furthermore, the total differences of workloads between operators also reduced with higher number of percentage which is 55.8%. The straight line show 15.6 second difference and the U-shape line show 6.9 second difference between operators. It means the workload of both operators was distributed well and approximately equal due to the smaller gap of the value.

Table 3: Comparison of workload between operators (in second)

Workload	Before (in second)	After (in second)	Time Reduce (%)
Operator 1	58.7	57.7	1.7 %
Operator 2	74.3	64.6	13.1 %
Differences between Operators	15.6	6.9	55.8 %

4.4 Line Balance Loss

From table 4, the line balance loss for straight line is 35 second and the line balance loss for U-shape line is 5.7 second. This shows that there is higher time loss for operator when working in straight line layout than U–shape line. The operators in straight line suffers 35 second in term of time loss which it shows that the distribution of workload among operators are not balance. In other hands, the operators in U–shape line show a little time loss which is 5.7 second. The smaller value of time loss indicates that the workloads among the operators are approximately equally distributed.

Table 4: Line balance loss comparison

Line Balance Loss	Before (Straight line)	After (U-shape line)
Time (sec)	35 sec	5.7 sec
Man Power	0.4	0.09
Balance Efficiency (%)	79.2 %	95.5 %

In term of manpower, the line balance loss for straight line is 0.4 man power. Meanwhile, the line balance loss for U-shape line is 0.09 man power. The value shows that inadequate of man power will occurs when there are only 2 operators in the straight line layout. By default, the straight line layout needs to increase of 0.4 man power to make the line more balance. In other hands, the man power loss in U–shape line layout is only 0.09 man power. The value is quiet small which means two operators require to perform the task is significant for the U–shape line.

Table 4 also reveals that the line balance efficiency for straight line is 79.2 % and the line balance efficiency for U-shape line is 95.5 %. It shows that the straight line layout is not balance compare to U-shape and it’s not suitable to perform the assembly task for that particular product. In this case, one operator have to perform a small amount of workload with a low cycle time compare to the other operator who need to perform a high amount of workload with higher cycle time. This will affect the workload distribution and as the result the workload between operators are not equally distributed. In other hands, the U–shape line layout has a high line efficiency which is 95.5 %. This means that U–shape line layout are more balance and suitable to use in performing the task. Both operators need to perform approximately equal workload with efficient cycle time where there are no major time differences between the operators. Indirectly it will motivate operator to produce higher output because they feel happy with the fair distribution of workload and work as a team.

5. Conclusions

Assembly line balancing is very crucial in manufacturing sector nowadays. The assembly line needs to balance so that the line has the high value of efficiency. Higher value of line efficiency indicates that the line have the approximately equal cycle time between operators along the line. Beside that, the workload between operators also distributed equally which make the higher line efficiency. In this paper, the time consume to complete assemble the product between two types of layout which are straight line and the U-shape line are studied. Results from this study shows that the value of line efficiency has increase after the redesign of the line layout take place. It can be conclude that the company made the correct decision in changing the assembly line layout from the straight line to the U-shape line. Further research need to be attempt on the others aspect of improvement activity in order to increase the line efficiency. Besides that, the company may try to use other types of line layout for study the line efficiency value so that the company may have more option in choosing the most suitable assembly line for their product.

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