



# IMPROVEMENT OF OVERALL EFFICIENCY OF PRODUCTION LINE BY USING LINE BALANCING

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## ABSTRACT

This project presents optimum efficiency improvement of the automotive jack assembly production line by using line balancing in AutokeenSdn. Bhd. (AKSB). Implementation of Lean to regulate works on floor has increase the manufacturing performance. Several improvement steps have been applied throughout the project to measure impact of improving the current system such as rearranging the arrangement of the parts, eliminating unnecessary activities of the assembly processes, reducing the cycle time, and balancing manpower workload using line balancing through Yamazumi chart and Takt time. The results of the improvement have been compared to the current system in term of the value of efficiency of the production line.

**Keywords:** lean manufacturing, line balancing, yamazumi chart.

## INTRODUCTION

In order to obtain the maximum production, company must manage the production line very well. In this case, a systematic technique or approach should be introduced. One of the techniques is line balancing technique. The used of line balancing technique was proved able to increase the productivity of the company. Lean manufacturing is the technique of production control for eliminating the waste from the manufacturing process. Lean manufacturing also focus on cost reduction through eliminating unnecessary activity by applying management philosophy which focused on identifying and eliminating waste from each steps in the production chain (Rahani and Muhammad Al-Asyraf, 2012).

Lean challenges the principle of economy of scale, which says the larger the production run will lower the cost per unit (Kazujiro Yamashita, 2004). Benefits of lean manufacturing are reduce inventory, less process waste, less rework, reduce lead time, financial saving and increase process understanding (T. Melton, 2005).

Lean manufacturing has its roots in automotive industry. It is based on the Toyota Production System (TPS), which is a system designed to provide the tools for people to continually improve their work (Robert, 1997). According to the lean idea, one of the main inhibitors of value flow is inflexibility. It is important to reduce inflexibility in order to shorten lead time, to lower stocks, to quickly respond to changes in demand, and to achieve just in time production (Mate Haragovics and Peter Miscey, 2014).

An assembly line is a cycle of workstations at which tasks related to assembly of a product are performed (Becker and Scholl, 2006). A common objective for assembly line balancing is to minimize the number of work-stations for a given cycle time and minimize of cycle time for a given number of work stations (K. Agpak and H. Gokcen, 2005). Simple assembly line balancing problem is based on a set of limiting assumptions (N. Boysen *et al.*, 2007). There are two well-known types of these problems (NimaHamta *et al.*, 2011):

1. SALBP Type 1 intends to assign tasks to workstations such that the number of station is minimized for a cycle time which generally happens when the organization desires to design new assembly lines.
2. SALBP Type 2 aims to minimize the cycle time, maximizes the production rate for a specific number of stations. This problem is suitable for the available systems which intend to improve their line efficiency.

Cycle time is defined as the time it takes to do a process (Kazuhiro, 2004). It includes the time from when an operator starts a process until the work is ready to be passed on. This company defines the calculation to get cycle time as follows:

$$\text{Range} = CT \text{ max} - CT \text{ min} \quad (1)$$

CT max = Cycle time maximum

CT min = Cycle time minimum

$$\text{Allowance} = \frac{\text{Total AT min} - \text{Total CT min}}{\text{Total range}} \times \text{Range} \quad (2)$$

Total AT min = Minimum of total actual time

Total CT min = Minimum of total cycle time

$$\text{Work Element Time} = CT \text{ min} + \text{Allowance} \quad (3)$$

$$\text{Work Station Cycle Time} = \text{Total of WET} \quad (4)$$

WET = Work Element Time

Takt time is the principle that all activity within a business is synchronized by a pulse, set by the customer demand (Rahani and Muhammad Al-Asyraf, 2012). Takt time determines the pulse of the Production System which is pace of sales, links production activity to actual customer demand, and ensures all the production activity will be synchronized from first process to final assembly process. Takt time relates the customer demand to the time



available. Takt time can be obtained by using the following formula:

$$Takt\ Time = \frac{PT\ Available\ per\ day}{Customer\ Demand\ per\ day} \quad (5)$$

PT = Production Time

The man power required to the production line can be obtained by using formula below:

$$Man\ power = \frac{Total\ Work\ Station\ CT}{Takt\ Time} \quad (6)$$

Yamazumi chart is used as a tool to proceed Kaizen for line balancing (Ahmad Naufal Adnan *et al.*, 2013). Yamazumi chart is a bar chart that shows the total cycle time for each operator when performing their process in the production flow. The method to prepare the Yamazumi Chart are firstly, use the actual basic cycle time data, obtained from the time measurement sheet. Secondly, build bar chart from accumulated cycle time for one operator. Make sure the walking time and hard work time are separated. The last step is arranging the operator at horizontal axis and draw takt time line to the time axis. Yamazumi chart also can be applied after doing the improvement (Kaizen) by adjusting the balance of takt time and cycle time. The aim for this step is for reduction of cycle time by kaizen of process.

An important measure of performance for a production line is the system throughput such as the average number of jobs produced per hour. Efficiency is the ratio of the current productivity level to the best practice productivity level. Best practice is defined as the largest productivity achievable (Chia Yen Lee, 2004). The efficiency of the production line can be obtained by using following formula;

$$Efficiency = \frac{Total\ Work\ Station\ CT}{Takt\ Time \times Number\ of\ Workers} \times 100 \quad (7)$$

## CASE STUDY

The purpose of this research is to demonstrate implementation of lean tool in order to improve overall efficiency of production line. The research is focus on

automotive jack assembly production line at AutokeenSdn. Bhd (AKSB) by leveling work cycle through a few kaizen activities. The research is carry out as follows.

## Observation of current layout

Automotive jack assembly production line of the AKSB consists of seven workstations. Each workstation carry out different process with specific work sequences to produce one complete product. The main activities are assembling of jack components. During the observation, essential data like waste on floor, customer demand, production flow had gathered for the analysis purpose. The workstations at the automotive jack assembly production line are shown in Figure-1.

## Measurement of current cycle time

The cycle time for each workstation was measured from the start picking part until it has been located at the next workstation. The cycle time was measured and recorded based on work sequences determined during observation. To enhance the reliability of the data obtained, video camera was used in recording. This is to get accurate data of work time. Every work step and time then was recorded in time measurement sheet to determine the cycle time of the process. From the videos recorded, the cycle time for workstation has been calculated by using time measurement check sheet as shown in Figure-2.

The data in the time measurement check sheet in Figure-2 is the cycle time for Workstation 5. The value of cycle time of step 1 is calculated using Equation.1 to Equation. 4. Based on Equation. 1, the value range obtained is 0.67 seconds. Value of allowance is obtained based on Equation. 2 which is 0.23 seconds. The value of work element time is obtained using Equation. 3 which is 1.55 seconds. The cycle time for workstation 5 is obtained based on Equation. 4 which is 9.71 seconds. The cycle time for other workstations are calculated using same equation as Workstation 5. The cycle time for each workstation is shown in Table-1. All the information obtained for the observation was used for cycle time analysis.

**Table-1.** Current cycle time for each work station.

Work station	1	2	3	4	5	6	7
Cycle time (s)	53.59	56.17	93.6	14.26	9.71	38.57	62.64

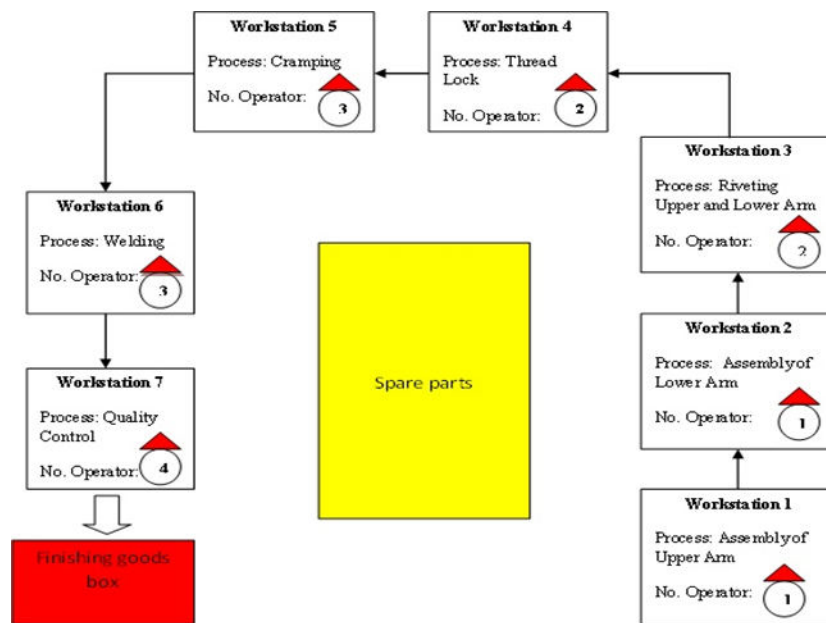


Figure-1. Current layout.

LINE		TIME MEASUREMENT CHECK SHEET										MEASUREMENT DATE		Rank	Allowance	Work element time	Problem
PROCESS	Cramping Process											MEASUREMENT TIME					
PART												MEASURER NAME	NURUL AIN ARBAAI				
NO	Process	1	2	3	4	5	6	7	8	9	10	x max	x min	Range			
1	Take the jack from racking.	1.43	1.89	1.99	1.32	1.61	1.95	1.64	1.34	1.88	1.45	1.99	1.32	0.67		0.23	1.55
2	Put the jack at the cramping machine.	1.03	1.77	1.65	1.23	1.64	1.05	1.43	1.65	1.65	1.98	1.98	1.03	0.95		0.33	1.36
3	Setting the jig.	1.09	1.76	1.66	1.65	1.92	1.63	1.65	1.99	1.65	1.87	1.99	1.09	0.9		0.32	1.41
4	Push button to apply cramping.	1.93	1.45	1.77	1.03	1.55	1.23	1.42	1.43	1.34	1.99	1.99	1.03	0.96		0.34	1.37
5	Cramping process.	1.22	1.03	1.01	1.45	0.98	1.32	1.21	1.03	1.04	1.11	1.45	0.98	0.47		0.16	1.14
6	Take the jack out from the cramping machine.	1.72	1.55	1.32	1.93	1.92	1.21	1.33	1.32	1.34	1.99	1.99	1.32	0.67		0.23	1.55
7	Put the jack at the racking.	1.37	1.64	1.73	1.55	1.63	1.72	1.03	1.88	1.32	1.67	1.88	1.03	0.85		0.30	1.33
ONE CYCLE TIME		9.79	11.09	11.13	10.16	11.25	10.11	9.71	10.64	10.22	12.06		7.8	5.47			9.71

Figure-2. Time measurement check sheet.

### Cycle time analysis

Takt time calculation is determined based on Equation. 5, the value of takt time for the production line is 134.4 seconds with working time of 720 minutes and rest time of 115 minutes. Takt time value then is used as targeted time to balance the workload among workers.

Plotting cycle time value on the Yamazumi chart is done to describe current workload of worker. The Yamazumi chart for the current condition is shown in Figure-3. Based on the current workload of the worker (see Figure-3); the workload of each worker is not balanced. The cycle time for worker number three and four differ too much than worker number one and two.

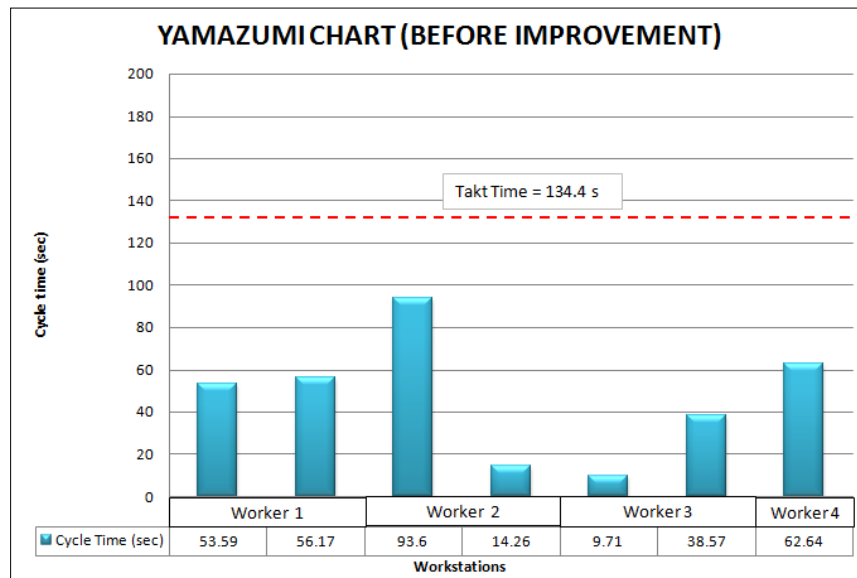


Figure-3. Current Yamazumi chart.

Calculating number of worker required based on takt time is carry out using Equation. 6. From the Yamazumi chart obtained, the workload of each worker can be determined by total up the cycle time of each worker. Based on Equation. 6, only three man powers required to the production line rather than current condition. Therefore, improvement activity needs to be carried out to meet the target number of man power.

### KAIZEN ACTIVITY

After gathering and analyzing data is completed, the next step is implementing Kaizen activity that aimed to eliminate the waste and improve current condition of production line.

#### Optimizing the work sequence

The cycle time can be reduced by eliminating or minimizing 7 types of waste. Non-value added steps or waste had been identified and segregated for elimination purpose. The improvement activity was introduced to waste elimination in work process step. Then the sequence of steps were arranged in order to optimize the motion and work of operator inside the work place. Wastes which were identified inside working area are over process method, excess of motion and unorganized work sequence. Figures 4 and 5 show before and after implementation of Kaizen activity.

#### Arrangement of parts

During the observation of process, parts are not arranged in proper location and far from the worker. Thus it makes operator to walk to part storage area to pick before return back to the work station. Therefore increase the time taken to take part by the worker. Part arrangement activity was done by considering the distance between part and worker, suitable picking method by worker as well as method to supply parts from part supplier. The part inside

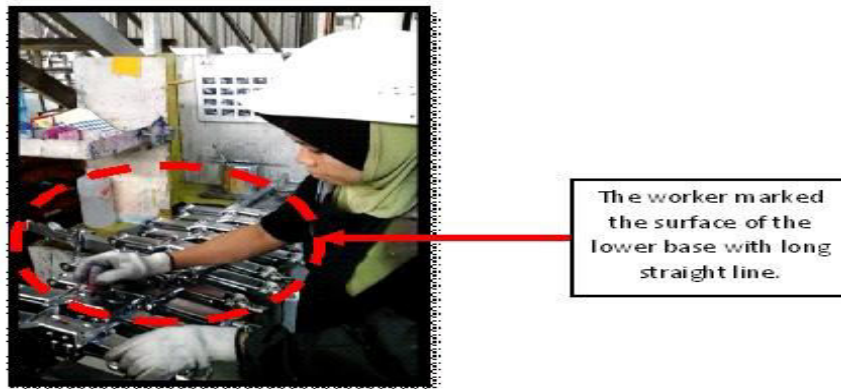
working place were arranged accordingly to ensure that the cycle time taken is not increase and the flow of work sequence is not changed. Figures 6 and 7 show part arrangement at production line.

#### Arrangement of manpower according to Yamazumi chart

Based on the current condition, the number of manpower at automotive jack assemble production line are four man powers. From the analysis the manpower required is three man powers. Therefore, the number of man power has been reduced from four man powers to three man powers. Therefore, the flow movements of the workers have been changed in order to balance the workload of each worker. Worker 1 has to do the task of workstation 1 (assembly and riveting upper arm), workstation 4 (thread lock), and workstation 6 (welding). While worker 2 has to do the task of workstation 2 (assembly and riveting lower arm) and workstation 7 (quality control) and worker 3 has to do the task of workstation 3 (assembly and riveting upper and lower arm) and workstation 5 (cramping process). After changing the flow movement, the total cycle time for each worker have been balanced. The total cycle time for worker 1 is 106.42 seconds, worker 2 is 100.8 seconds, and worker 3 is 103.31 seconds. The balanced workload can be shown in the Yamazumi Chart in Figure-8.

#### Evaluation of efficiency after improvement

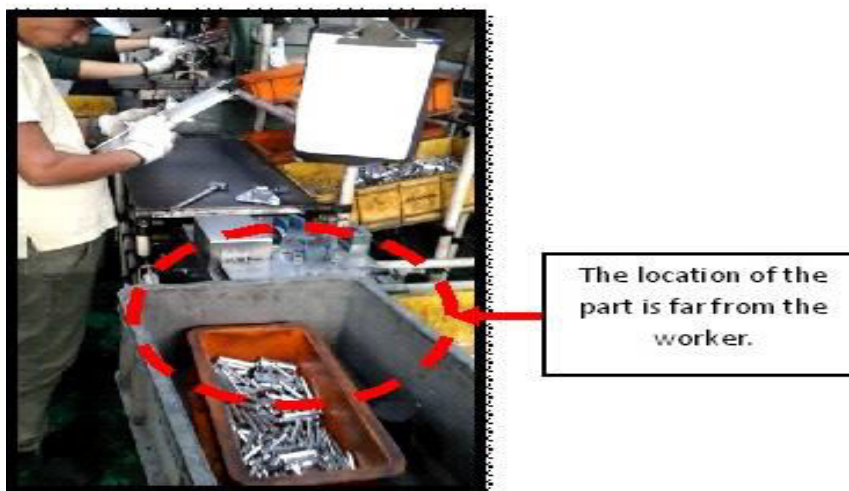
Using Equation. 7, the efficiency of production line has been calculated based on the cycle time in current condition and after improvement. The evaluation is carried out by comparing the efficiency value of both conditions. The efficiency has increased from 61 percent to 77 percent due to the reduction of cycle time to 310.53 seconds. Table-2 shows cycle time after improvement.



**Figure-4.** Work step before Kaizen activity.



**Figure-5.** Work step after Kaizen activity.



**Figure-6.** Part arrangement before Kaizen activity.





Figure-7. Part arrangement after Kaizen activity.

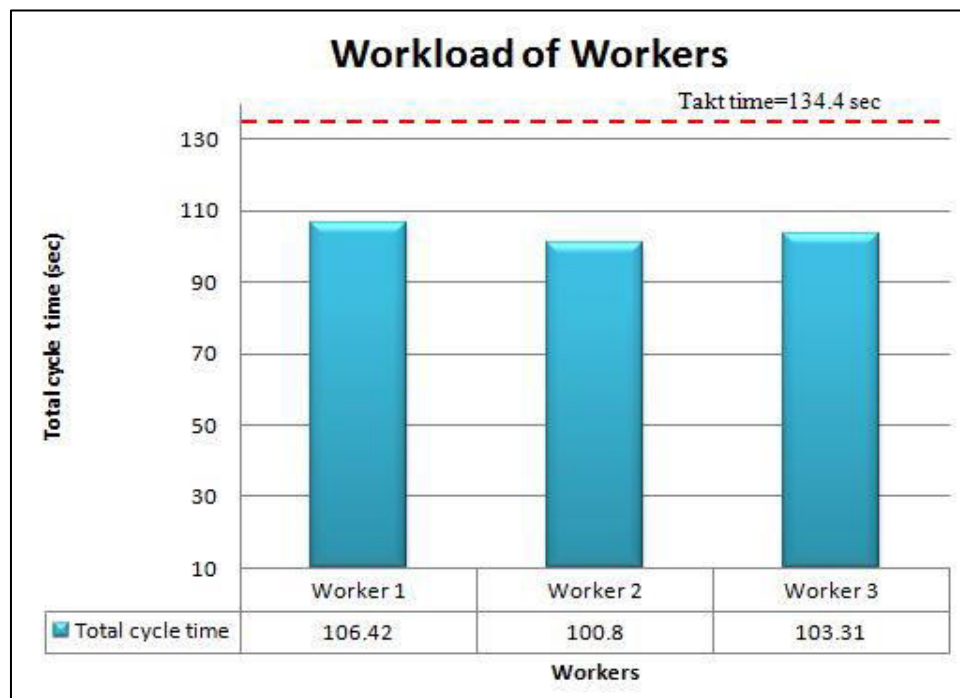


Figure-8. Workload of each worker after arrangement of manpower.

Table-2. Cycle time after improvement.

Workstation	1	2	3	4	5	6	7
Cycle time (s)	53.59	38.91	93.6	14.26	9.71	38.57	61.89

## CONCLUSION AND RECOMMENDATIONS

As conclusion, by using line balancing method in this project has proven that greatly improved the losses occurred in the line beside create better production rate and quality of the company's production. The company has increased the efficiency of the production line to 77 percent, reduced number of manpower from four manpowers to three manpowers and balanced the

workload of each worker. Besides that the company also had increased the space utilization on manufacturing floor. It is recommended that the company should use jig machine at Workstation 1 to increase the efficiency of the workstation by reducing the cycle time. Current assembly process for lower arm of automotive jack is not using jig machine while the assembly process of upper arm is using jig machine. From the observation, the assemble process of upper arm is more efficient, the jig machine used has



provided repeatability, accuracy, and interchange ability in the assembly process. Thus, the assemble process using jig machine has lower cycle time than the assemble process without using jig machine. It also is recommended that the company should implement this pilot study improvement activity for the other production lines to achieve long term benefits and high quality products.

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