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STANDARDIZED WORK IN TPS PRODUCTION LINE

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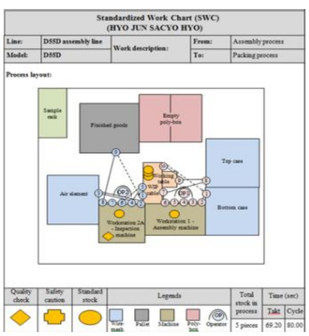
Graphical abstract



Abstract

This paper presents a case study implementation of one of the Toyota Production System (TPS) tools, known as Standardized Work (SW), in an automotive assembly line in Malaysia. The main functions of SW are to design, develop, document and visualize a set of a manufacturing process with detail and proper study of it. SW is conducted to raise production consistency and quality of a produced product and the job performed. With the proper SW implementation, good results have been obtained from the increase in efficiency, productivity, quality and process stability of the operator's performance. Thus, the findings are consistent with TPS philosophies which are waste elimination and continuous improvement in any manufacturing area.

Keywords: Standardized work, Toyota production system, automotive production line, Kaizen

1.0 INTRODUCTION

Standardized work (SW) is one of the most powerful lean tools that can be used to establish the best and most reliable work practice and sequences for each process, machine and worker. SW is designed by detailed study and observation of the process, based on products' and customers' requirements [1]. The main objectives are to minimize process variation among the workers, to eliminate unnecessary motion or non-value-added (NVA) tasks, and to produce good quality product, safely and economically [2].

Toyota Production System (TPS), SW is important and most recommended for maintaining any improvement or kaizen activities as Liker and Meier [1] cite Misaki Imai: there can be no kaizen without standardization". SW forms the baseline for kaizen and as the standard is improved, the new standard becomes the baseline for further improvements, and so on. Therefore, improving the standardized work is a never-ending improvement process [1] and has been applied successfully by many companies [6, 8].

In the context of manufacturing field, SW is defined as a detailed and documented department visual system provided by management to be the main reference for the production department, especially line operators in managing their processes by following a series of tasks [1]. SW provides the best reference for management to train new workers on the optimum way to perform the process and eliminate waste confidently, consistently, efficiently, safely while ensuring quality, defect-free and on-time delivery [2].

This paper focuses on the systematic application of SW in an automotive assembly production line which currently in the process of transition from conventional to TPS in order to sustain in the industry. The SW is applied in order to evaluate and establish a new standard process procedure for the line after improvement or kaizen activities. The performance of the line with the new procedure has been evaluated through lean metric comparison against the existing process.

2.0 CASE STUDY

The case study area is an assembly line producing automotive components for local automotive assemblers in Malaysia. The line produces Air Cleaner Module (ACM) on a one-shift operation for 12 hours a day. There are 2 workstations in this line which are workstation 1 for assembly process by operator 1 and workstation 2 for inspection process by operator 2. This study focuses on the assembly process at workstation 1. The process is a semi-automated with manual loading and unloading at the start and the end of the process. The product is carried from the first workstation to the next workstation manually by hand. The operator has to assemble all the components on the plastic case manually, and then it was fitted or clamped by using an assembly machine. The operator performed the tasks according to cycle time given by management and the outputs were monitored in hourly basis. Table 1 shows the average performance of the line for the past five months.

Table 1 Previous manufacturing data

Manufacturing data	Target	Actual					
		Month 1	Month 2	Month 3	Month 4	Month 5	Average
Output per shift (pcs)	510	470.0	468.0	460.0	460.0	465.0	464.6
Overtime (hour)	100.00	195.75	311.42	172	209.05	159.6	193.56
Backlog (pcs)		408	780	349	460	294	458
Attainment (%)		96.11%	92.64%	97.19%	95.62%	97.38%	95.79%

With an average output of 45.1 pieces per man-hour, this line can be considered as did not capable to fulfill the daily requirement. Every day, the line is operated with 2.5 hours overtime, while weekends were considered as 12 hours of overtime. The overtime was applied to cover backlog that occurred almost every day. Through line observation, it was found that there are a lot of forth and back movements in the process and the line is congested with large storage equipment such as trolley, wire-mesh and poly-boxes. The bulk size of the storages requires a large space in the assembly area, thus increased walking distance.

3.0 WORK MEASUREMENT – TIME STUDY

For detailed analysis on how the current production processes were performed, time study was conducted. This is to record all the production activities including value-added (VA) and non-value-added (NVA) activities. The activity was conducted as suggested by J. Hazier and B. Render [3] and S. A. Lawrence [4]. Time Measurement Sheet (TMS) was used to record the times for each elements process. For accurate data analysis, each process element was timed for ten cycles to increase the accuracy of the data. All the collected data have been summarized in Table 2.

Table 2 Summary from time study for workstation 1

Workstation	Total hand time	Total walk time	Total machine time	Total actual CT (Mode)	Total CT (Minimum)	Total CT (Maximum)	Periodical time
Workstation 1	63.10	3.90	6.0	67.00	62.50	69.90	11.00

This data shows that the difference between minimum and maximum time is quite distinct. Therefore, it can be concluded that the operator's variance in perform the tasks is quite large.

4.0 STANDARDIZED WORK – THE ELEMENTS

To implement SW, there are three elements have to identify first which are:

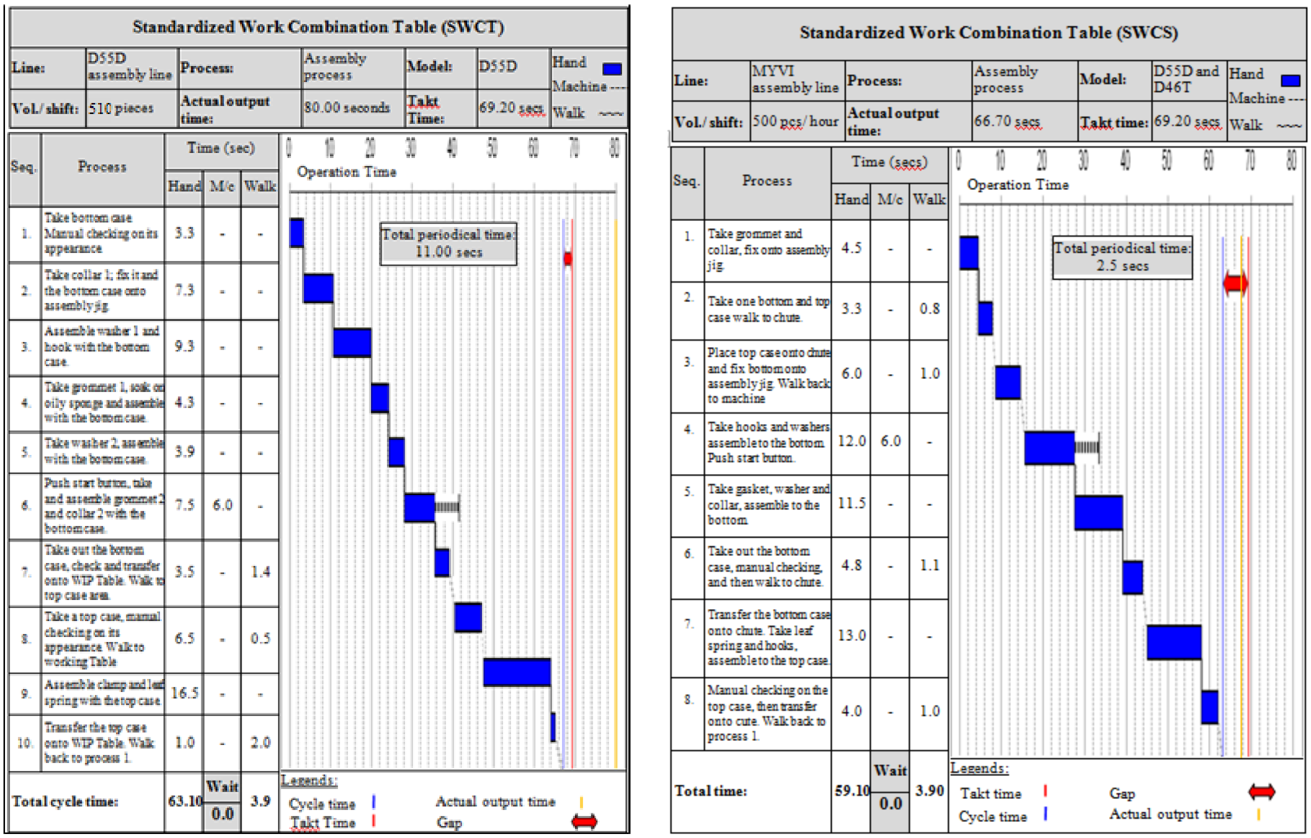
i. Takt time: is the time for one part needs to be produced or the pace that each incremental step must maintain based on available time and customer requirement to enable on-time delivery [1] Line Takt time (TT) for the past five months of production data were calculated and shown in Table 3. The formula used for calculating the takt time is as below [1]:

$$Takt\ Time = \frac{Total\ Time\ Available}{Total\ volume/Number\ of\ working\ days} \quad (1)$$

To establish the line takt time, minimum takt time from Table 3 was used which is equal to 69.20 sec. It is based on the maximum fluctuations of monthly volumes on this line.

Table 3 Takt time

Month	1	2	3	4	5
Takt time (sec)	73.94	69.62	71.3	73.8	72.48



(a) (b)

Figure 1 SWCT at existing workstation 1 (a) before kaizen, (b) after kaizen

ii. Standard Cycle time (CT): is the expected or historically average total production time per unit produced. In this paper, standard CT is calculated as below [1]:

$$\begin{aligned} Standard\ CT &= Actual\ CT + Periodical\ time \\ &= 67.0 + 11.0 = 78\ seconds \end{aligned}$$

iii. Work sequence: is a best method and a job sequence of process steps to produce a piece of part.

5.0 KAIZEN ACTIVITIES IMPLEMENTATION

In order to eliminate as much waste or NVA activities as possible as well as to reduce current CT, six major Kaizen activities were implemented which are:

i. Simplify and re-arrange the assembly processes by combining the elements process and movements where possible, as well as rearranging the process sequence and simplify the processes so the production would run below the takt time.

ii. Elimination of NVA activities such as periodical tasks, operator's movements, un-wanted checking and marking. 9.20 seconds of NVA times have been successfully eliminated.

iii. Workloads balancing between workstations to ensure the workloads are balanced and working at takt time without any unnecessary wait or idle time.

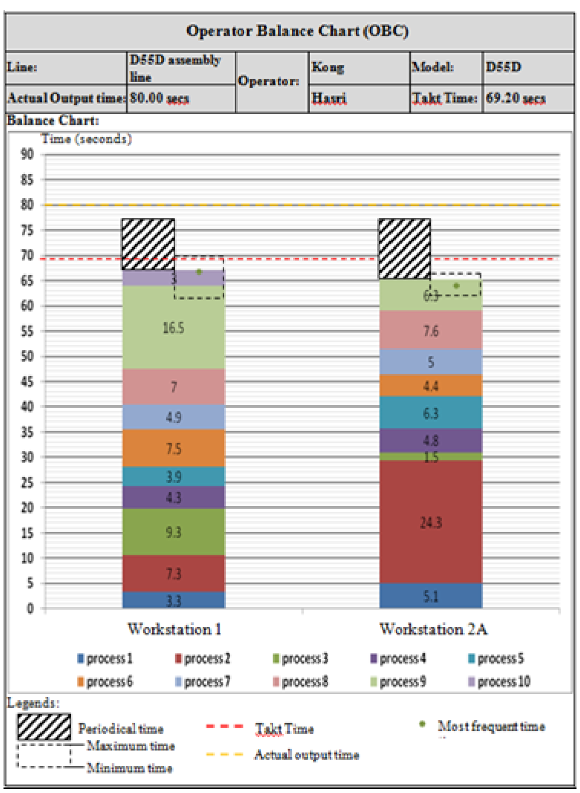
iv. Introduction of the GFR system to present the parts and components as close as possible to the operator's point of use as well as to reduce components stocks quantity in the line [5].

v. Line re-layout with the application of continuous flow manufacturing system and U-shape cell to improve line balancing and maximize communication between operators [7].

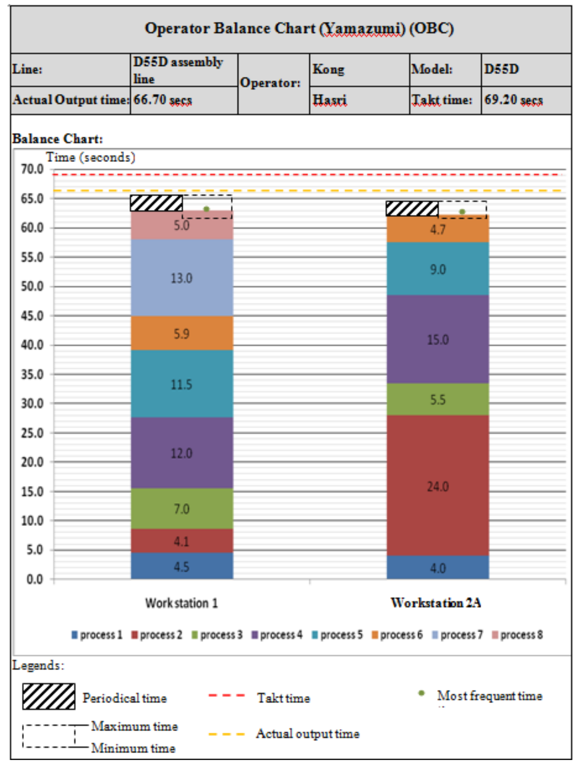
6.0 STANDARDIZED WORK – THE TOOLS

The first SW tool to be used is SWCT by transferring the data in the TMS into it. The main function is to demonstrate the time relationship between manual work, machine work, walking time and the takt time. It indicates the flow of operators work within the operation in a single work and how much time is needed for each element. Figure 1 shows the SWCT for workstation 1 with (a) before kaizen and (b) after kaizen. From the SWCTs, the vertical red line refers to the takt time; vertical blue line refers to new improved standard CT, while vertical orange dot refers to actual output time. It shows that the actual CT is 67.0 sec with 3.0 sec of idle time, far exceeded the takt time. However, after the kaizen, the CT and output time are lower than the takt time. Main reduction came from the reduction of hand (HT) and walk times (WT).

To visualize all the workloads and to compare the workloads between workstation 1 and 2 and to takt time, the second tool which is Operator Balance Sheet (OBS) or Yamazumi was used as shown in Figure 2 with (a) before kaizen and (b) after kaizen. Before kaizen, the actual output time has exceeded the talk time. This is the main reasons for high unplanned production overtime. After kaizen, the workloads between workstations were well balanced and below the takt time. Moreover, the actual output time was also reduced and less than the line takt time.



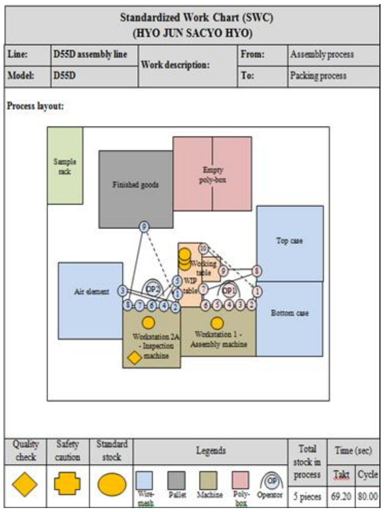
(a)



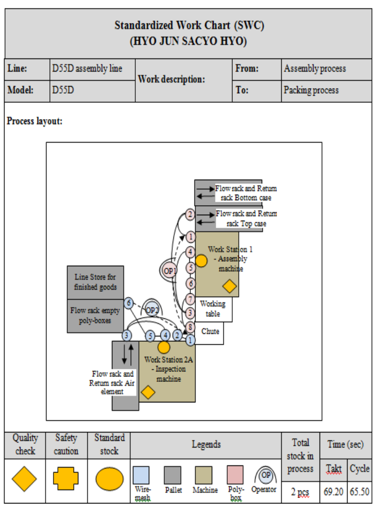
(b)

Figure 2 OBC at existing D55D assembly line (a) before kaizen, (b) after kaizen

To analyze the layout and the movements of the operator, the third tool which is Standardized Work Chart (SWC) was used. Figure 3 shows the SWC at the line with (a) before kaizen and (b) after kaizen. Before kaizen, this line was designed in open U-shaped with operators moving around their own working areas. The production flow is not considered continuous as there are high standard in-process stocks in the process which is located on the WIP table between the workstations. There are workloads imbalance between workstations resulted in line bottleneck and high in-process stock. With the current size of 22m³, this assembly line looked congested with three wire-meshes, two pallets and one WIP table which was located around the workstations.



(a)



(b)

Figure 3 SWC at existing D55D assembly line (a) before kaizen, (b) after kaizen

These conditions increased the operators' movement and CT. After kaizen, the area was reduced to 18m³. The main reductions came from the introduction of a GFR system to replace the existing wire-meshes and pallets. Through this activity, operators were trained to use both their hands simultaneously, as illustrated in Figure 4. The operator has to grab and handle a lot of small components along the assemble processes. For this purpose, the location of boxes was re-arranged and placed nearer to the operator for easy access and stacked according to process sequence depending on the components to be assembled.

Figure 4 Operator uses both hands during pick-up plastic parts from poly-box

Through re-layout activity, the improved layout was designed in open U-shaped cell. Distances of movements of both operators have been reduced by keeping them move within the optimized workspace as short as possible and to get them well to communicate each other. Chute was introduced to replace the existing WIP table to allow minimum standard in-process stock on the line, as to allow the assembly process to continuously flow.

After being satisfied with the performance of the improved line, results collected were evaluated again to establish final results. Table 4 illustrates the identified Lean metrics as listed in Cell Kaizen Target Sheet (CKTS) for results comparison.

From the CKTS above, line CT was reduced by 16.0%, which is from 78.0 sec to 65.5 sec, managed to be lower than line takt time. Subsequently, it increased also production output from 45 pieces to 54 pieces per man hour and attainment from 95.79% to 98.95%. Average overtime was reduced from 193.56 hours to 55.0 hours per month. The last metrics show that the shop floor area was managed to reduce by 18.18%, which is from 22m³ to 18m³. In addition, the improved line is now fully operating under continuous flow manufacturing system. Under this system, parts can be produced much faster, resulting in profits being collected in a shorter period of time.

Table 4 Cell Kaizen Target Sheet (CKTS)

Cell Kaizen Target Sheet (CKTS)				
Metrics	**Note**	**Existing**	**Final Achievement**	**% Increase/ Decrease**
Line cycle time (sec)	Actual CT + Periodical time	78.00	65.50	17.60% Decreased
Production output	Pieces Per man hour	45	54	16.67% Increased
Overtime (hour)	Total average overtime	193.56	55.00	71.59% Improved
Attainment (%)	Total hr/ month	95.79	98.95	96.81% Improved
Shop floor area	Size of the case study area	22 m³	18 m³	18.18% Decreased

6.0 CONCLUSION

After the implementation, significant achievements relevant to the semi-automated and flexible assembly area mainly in the studied area, were generated. Therefore, it can be concluded that the success of SW implementation is provided in a systematic manner with the help of effective data collection and analysis, a set of SW tools and implementations of Kaizen activities.

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