SIMULATION STUDY TOWARDS PRODUCTIVITY IMPROVEMENT FOR ASSEMBLY LINE

Effendi Mohamad[1], Teruaki Ito[2], Mohd Rizal Salleh[3], Noor Aniza Nordin[3]

[1]Graduate School of Advanced Technology and Science
University of Tokushima, 770-8506, Tokushima, Japan

[2]Institute of Technology and Science
University of Tokushima, 770-8506, Tokushima, Japan

[3]Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka, Malaysia

Email: effendi@utem.edu.my, tito@tokushima-u.ac.jp
rizal@utem.eud.my,noor.aniza@upeca.com

ABSTRACT

To compete in an ever growing manufacturing environment, companies have to improve their productivity. This study describes the improvement activities of the ABC Company in Malaysia, using a line balancing technique. With these improvement activities, the company managed to reduce the total time required to complete 600 product units per week, from 256.49 hours down to 208.06 hours, and the lead time from 5 days 7.9 hours down to 4 days 6.8 hours. This study also proposes assembly line improvements, using simulation methods, by focusing on a Material Handling Operator (MHO) solution. A MHO is assigned to a transport box container, from one station in the assembly line to another, so that operators at each workstation can concentrate on their own tasks. Using a process simulation approach, this paper compares the performance of the production model using MHO with that of a production model without MHO. The feasibility of this solution is then discussed.

KEYWORDS: *line balancing, productivity, simulation, modelling, material handling.*

1.0 INTRODUCTION

Assembly line is a flow oriented production system. It consists of productive units performing the operation (workstation) and movement of work pieces from one station to another using some kind of transportation system. To optimize the workstation or assembly line throughput, line balancing is used. With line balancing, production time and cost can be reduced, and production output can be maximized. Basically, line balancing is a technique that can affect productivity. Non-value added activities can be analysed and eliminated to increase productivity. The purpose of this study is to increase the productivity of the ABC Company through a line balancing technique and propose improvements using a simulation model.

2.0 DESCRIPTION OF THE EXISTING SYSTEM

The manufacturing system analysed in this study, is an assembly line for Product A in the ABC Company, in Malaysia. The assembly line is divided into two sections, namely Front Assembly Line and Back Assembly Line. Front Assembly Line consists of five workstations, namely Decoder programming (WS1), Decoder build (WS2), Decoder test (WS3), Radio build (WS4), and Case back assembly (WS5). Back Assembly Line consists of four workstations, namely Alignment process (WS6), Final case-up assembly (WS7), Final test (WS8), and Customization (WS9). Each workstation is managed by one workstation operator.

Table 1: Time study for Product A

Workstation (WS)	Process	Time Study: Cycle Time (sec)										
		1	2	3	4	5	6	7	8	9	10	Average Time
WS1	Decoder Programming	69.2	72.4	72.4	73.4	79.7	79.6	69.3	73.4	75.4	70.1	73.49
WS2	Decoder Build	296.1	350.7	309.3	345	312.2	340.5	345.2	337.1	322.9	350.8	330.98
WS3	Decoder Test	73.5	72.8	75.8	76.5	78.9	73.3	65.3	68.4	76.5	73.4	73.44
WS4	Radio Build	220.2	231.1	209.3	220.3	226.1	233.2	211.7	218.6	210.8	225.6	220.69
WS5	Case Back Assembly	114.9	121.7	117.4	124.3	127.3	125.7	131.5	133.9	145.5	145.4	123.26
WS6	Alignment Process	201	216.8	191.7	216.6	218.3	260.8	235.1	202.8	203.1	228	217.42
WS7	Final Case-up Assembly	195.4	216	231.8	215.6	224.5	227.2	214.8	218.9	231.2	226.1	214.65
WS8	Final Test	100.4	116.6	111.5	115.5	116.4	108.9	114.9	115.4	116.6	122.2	113.84
WS9	Customization	176.8	172.5	180.4	181.4	178.2	177.4	193.5	180.7	181.2	189.5	181.16
Total Cycle Time (sec)												1548.93

The productivity of the ABC Company is unsatisfactory and fails to achieve its target output. Therefore, a line balancing technique is used in this study to determine the problems occurring in the ABC Company. In order to perform line balancing, a cycle time is needed. In this study, ten samples of cycle times were recorded for every workstation and their averages were noted. The total cycle time is 1548.93 sec (Table 1). Working time per day of Product A is 8.65 hours, including rest time (155 700 sec/week), while the demand for Product A is 600 units per / week. The takt time is 259.5 sec/unit. It was calculated that the process bottleneck occurred at Decoder build (WS2), because it could only produce 470 units per week, compared to the demand (Table 2).

Table 2: Workstation capacity to produce Product A

Workstation (WS)	Cycle time (sec)	Formula (Working Time / cycle time)	Product produced
WS 1	73.49	155 700/73.49	2119
WS 2	330.98	155 700/330.98	470
WS 3	73.44	155 700/73.44	2120
WS 4	220.69	155 700/220.69	706
WS 5	123.26	155 700/123.26	1263
WS 6	217.42	155 700/217.42	716
WS 7	214.65	155 700/214.65	725
WS 8	113.84	155 700/113.84	1368
WS 9	181.16	155 700/181.16	859

3.0 PROPOSED MODIFICATIONS OF THE EXISTING SYSTEM

In order to reduce cycle time, a Yamazumi chart is constructed (Figure1). From the chart, non-value added activities can be identified and completely removed. Room for improvement (Kaizen) can be made by reducing the total work content. The total time required to complete 600 product units is 256.49 hours; therefore, the lead time for completion is 5 days 7.9 hours. The working time required to fulfil the product demand, ends at 5.15 pm, on Day 5. In order to complete this task, the operator needs to work overtime, which consequently, increases the cost. To avoid this, the WS2 process needs to be analysed using a Compiled Standard Operation Chart (Figure 2).

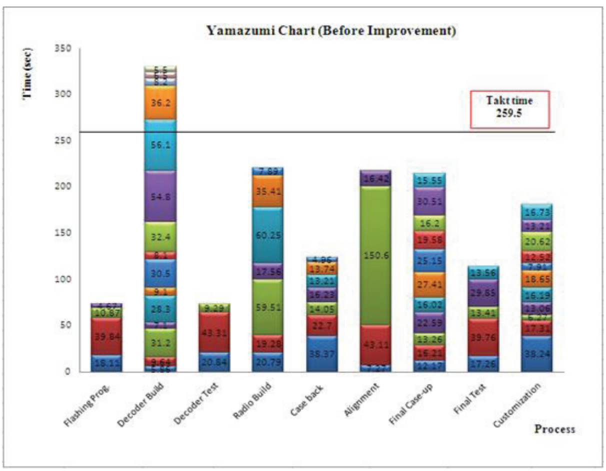

Figure 1: Yamazumi chart (before improvement)

The analysis shows that the steps that need improvement, in the Decoder build process, are fitting battery contact; fitting motor vibrates, fitting PCB plug 4-way, fitting battery 2 onto PCB, and soldering and fitting the support bracket into the display screen. Previously, soldering was done after the installation of each part onto the PCB, which took 178.5sec to complete. This process can be changed, so that soldering occurs after all of the parts have been installed onto the PCB; thus shortening the process by 53.3 sec to 125.2 sec. Other steps, such as fitting battery contact, motor vibrate, PCB plug, and Battery 2 onto the PCB, can be re-distributed. The total time to complete the installation for these four parts onto the PCB is 31.5 sec. Re-distributing them to a Flashing Programming (WS1) process will reduce this time to 28.31 sec.

Other steps that can be re-distributed are fitting the support bracket into the display screen, fitting the display screen onto the PCB, and inserting the display tail. These steps were previously done at the end of WS2, with a cycle time of 50.95 sec. By re-distributing them to a Decoder Test (WS3) process, the cycle time for these steps can be reduced to 45.23 sec. Therefore, the way to reduce cycle time in the WS2 process is to remove the tasks that can be done first, because they require no precedence constraints like the other tasks. After implementing these improved activities on the WS2 process, the cycle time is reduced from 330.98 sec to 180.12 sec.

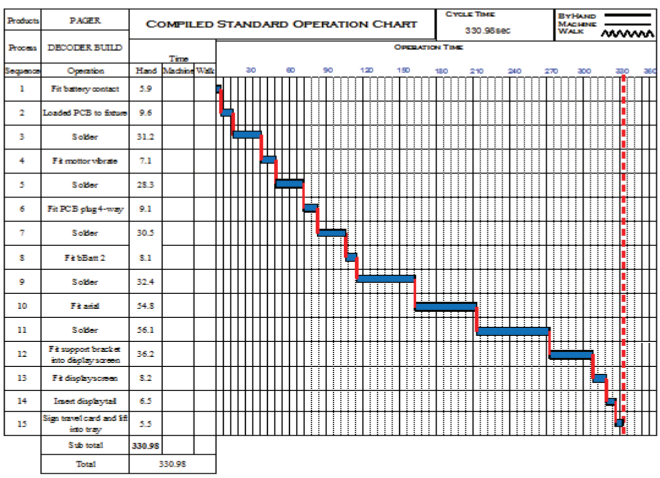

Figure 2: Compiled Standard Operation Chart for the Decoder build process (WS2)
(Before improvement)

Figure 3: A non-systematic arrangement area in the assembly production line.

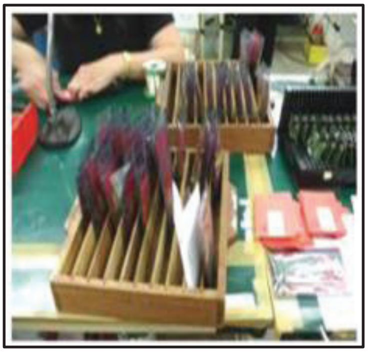

Figure 4: A large lot size

Another problem that was identified in the ABC Company is the unsystematic arrangement of the assembly line area. Assembly parts are scattered on tables and some parts are still packed in plastic bags at the time of assembly. It is both difficult and time consuming for operators to reach for and handle small parts during assemble, often leading to careless handling (Figure 3). Furthermore, operators are required to deliver large lot sizes (> 7parts) and parts are handed manually, from station to station, without proper material handling procedures (Figure 4). These inefficiencies lead to bottlenecks at some workstations, where parts become piled up.

Figure 5: The introduction of boxed containers

To solve this problem, material handling equipment or a set of boxed containers is introduced (Figure 5). The container keeps parts in good order, making them easily accessible, which not only reduces quality problems caused by poor handling, but also decreases the non-value added time. A smaller lot size of parts in the boxed containers is also introduced.

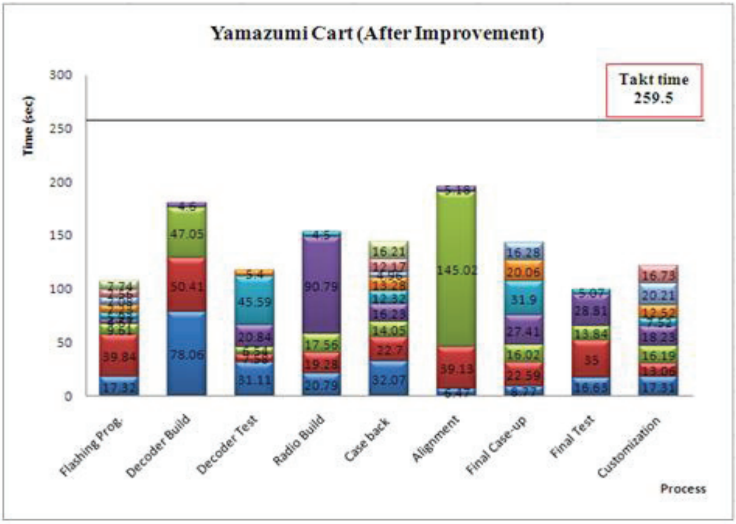

Figure 6: Yamazumi chart (after improvement)

An illustration of the improved assembly line activities in the ABC Company can be seen in the Yamazumi chart (Figure 6). With these improved activities, the ABC Company managed to reduce the total time required to complete 600 product units from 256.49 hours down to 208.06 hours, with the lead time reduced from 5 days 7.9 hours down to 4 days 6.8 hours (Table 3).

Table 3: Total cycle time (after improvement)

Workstation(WS)	Cycle Time (sec)	Process Time (sec) (C.Time * Demand)	Process Time (hour) (C.Time * Demand) / 3600
WS1	106.98	64188	17.49
WS2	180.12	108072	30.01
WS3	117.07	70242	19.3
WS4	152.92	91752	25.29
WS5	143.99	86394	23.59
WS6	195.8	117480	32.38
WS7	143.03	85818	23.5
WS8	99.35	59610	16.33
WS9	121.77	73062	20.17
Total	**1261.03**	**756618**	**208.06**

4.0 MODELLING AND SIMULATION EXPERIMENTS

4.1 Simulation

The next part of this study proposes improvements of the assembly line using simulation methods. Simulation is a kind of analysis method, which involves systems, models, and applications, to mimic the behaviour of real systems, using appropriate software on a computer. Simulation models can be used to analyse and measure the effects of changes on the manufacturing production line, without interrupting the actual manufacturing processes. Other advantages of simulation are that it can be done with less analytic requirements, it can be easily demonstrated, and experimental simulation runs can be done in a compressed time, because the model is simulated on a computer (Chung, 2004).

4.2 Material handling solutions on the assembly line

It is estimated that material handling systems represent 15 to 70% of the total cost of manufacturing a product. It is therefore a crucial area that can be optimized in a production line, in order to increase productivity (Ito & Mohamad, 2010). There are two general categories of material handling devices that are based on their modelling requirements. The first category constrains the number of simultaneous transfers, based on the number of individual material handling devices (e.g., carts, hand-trucks, people, AGVs, etc.), whereas the second category constrains the ability to start a transfer, based on space availability (e.g., conveyer, overhead trolleys, power-and-free system, etc.,) (Kelton et al., 2010).

In the previous section, the problem and solution for a non-systematically arranged area in the assembly line was discussed. With material handling equipment, the parts for Product A were well organized on each workstation, and performance improved. However, operators are required to manually deliver parts to the next workstation, which may cause bottlenecks at some workstations. Workstations become idle every time their operators walk away to deliver their boxed containers to the next station. Effective solutions are required to improve the performance of the production line.

Three solutions to these production line problems are studied in this research, namely Material Handling Operator (MHO), Automated Guided Vehicle (AGV), and conveyer. However, this study focuses only on the first solution, where one MHO is assigned to transfer boxed containers from one station to another. As a result, the operators at each workstation can continue to concentrate on their parts assembly task. Simulation models are created to evaluate the effect of MHO in the production line.

4.2.1 Simulation model based on an assembly line

Figure 7 shows the layout of the assembly line. This study focuses on the front assembly line. Two types of simulation models were designed. One without MHO (W/O-MHO Model), which is similar to the existing assembly line; and the other, with MHO (W-MHO Model), where one MHO is responsible for the material handling task of the entire production line. These models were verified using animation, and validated when the simulation's result was seen to be identical to the experimental result.

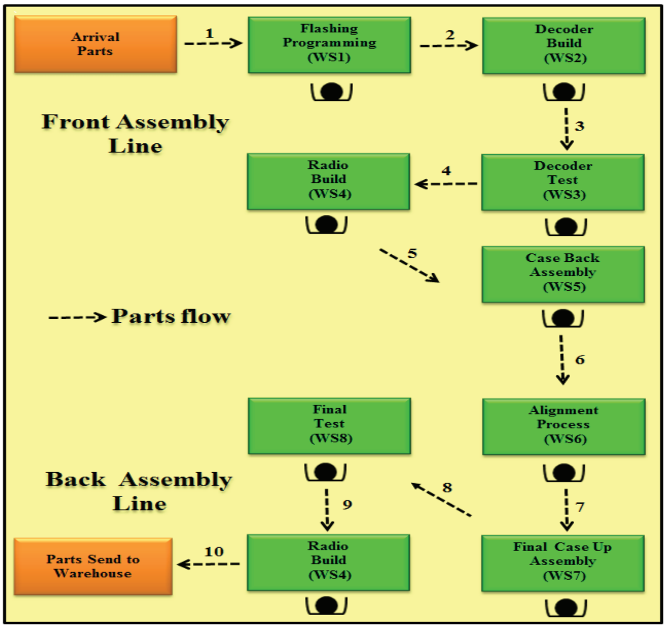

Figure 7: An overview of the assembly production line

Figure 8 shows a snapshot of the W/O-MHO Model, where the decoder programming operator (at WS1) is transporting parts to WS2, using a boxed container, whilst leaving WS1 idle. Figure 9 shows a snapshot of the W-MHO Model, where the MHO is transporting parts from WS1 to WS2 using a boxed container, whilst the decoder programming operator continues on-duty at WS1.

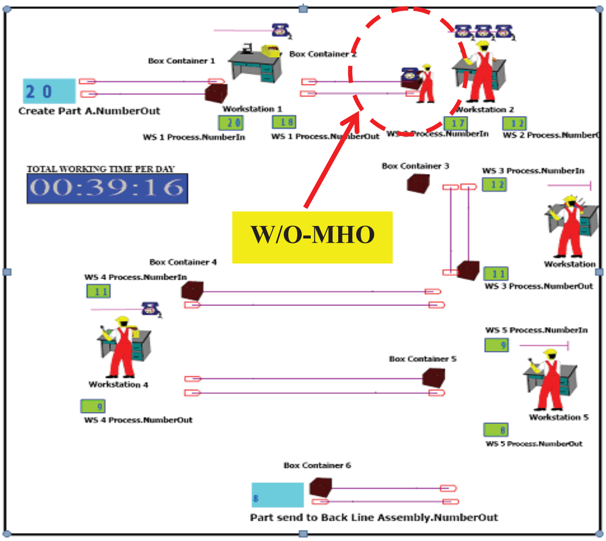

Figure 8: Snapshot of the W/O-MHO simulation

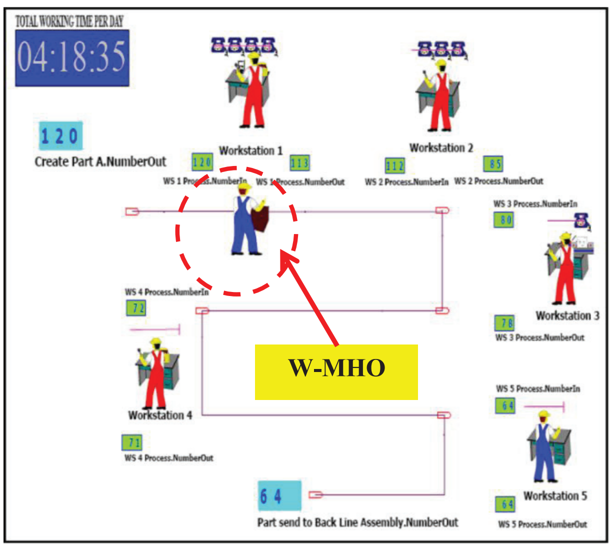

Figure 9: Snapshot of the W-MHO simulation

With these simulation models, comparison of process time and production performance can be made using simulation evaluation. Generally, the process time at each workstation in the W-MHO model was better than that of the W/O-MHO model (as shown in Figure 10). The production performance of the W-MHO model (3760 units/month) was also better than the W/O-MHO model (3100 units/month) (as shown in Figure 11); even though both models show a better performance than before the introduction of boxed containers.

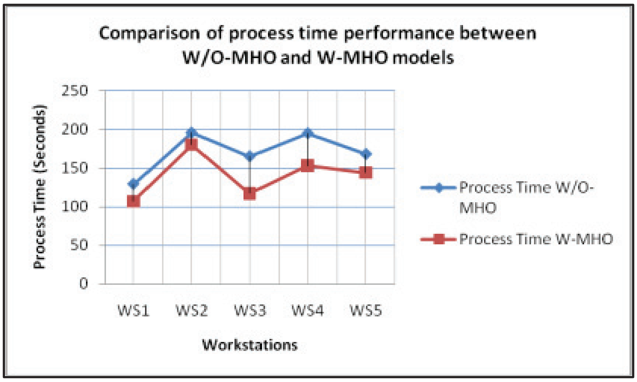

Figure 10: Comparison of process time performances between W/O-MHO and W-MHO models

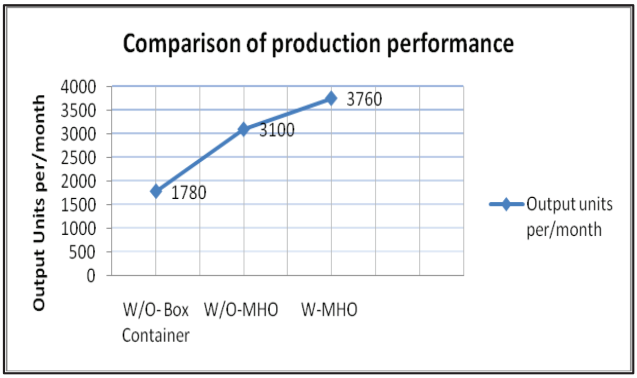

Figure 11: Comparison of production performance

5.0 CONCLUSIONS AND FUTURE WORK

The productivity of the ABC Company (for Product A) was successfully increased using a line balancing method. The ABC Company managed to reduce the total time required to complete 600 product units per week, from 256.49 hours to 208.06 hours; and reduced lead time from 5 days 7.9 hours to 4 days 6.8 hours. This paper also describes an overview of the material handling issue in the ABC Company and considers an MHO solution to solve this issue. Two types of simulation models were designed and implemented to work on this case study, using a simulation-based approach. The results presented in this paper showed that the process time performance of the W-MHO model was better than that of the W/O-MHO model in a simulated evaluation. Moreover, the introduction of an MHO also increased the company's total performance by approximately 20% compared to that of the W/O-MHO model. These results show the feasibility of a simulation-based approach for the comparison of performance. Further study is under way for other material handling solutions, including AGV and conveyor systems.

ACKNOWLEDGEMENT

The researchers would like to thank the Malaysian Government, Universiti Teknikal Malaysia Melaka (UTeM) and the University of Tokushima Japan, for their financial support and provision of facilities to carry out this study. The researchers would also like to thank the ABC Company for their cooperation in data collection.

REFERENCES

Chung, C. (2004), Simulation Modelling Handbook: *A Practical Approach,* CRC Press LLC.

Ito, T and Mohamad, E. (2010), "Simulation Study Towards Productivity Improvement in Manufacturing," Kyushu Branch of Japan Society of Mechanical Engineers, *Tokushima Conference*, No.105-2, pp. 125-126.

Kelton, W.D., Sadowski. R. P. and Nancy B. Sweets (2010), *Simulation with Arena*, Fifth Edition, McGraw-Hill International Edition.