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APPLICATION OF LEAN MANUFACTURING USING SIMULATION

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ABSTRACT

This study involves the use of simulation to improve the efficiency of the production line. The simulation model imitates a real production system so that improvement alternatives can be evaluated without disrupting actual production. The production process at an automotive components manufacturing is used as a case study. A value stream mapping is constructed to portray the system flow. A simulation based on the current value stream mapping (VSM) data of the production line is built using the WITNESS simulation software. Four alternative solutions are proposed to increase the productivity of the production line: (1) eliminating the idle machine; (2) reducing the number of operators at selected machine; and (3) combination of alternative (1) and (2). Analysis results show the capability of these tools to formulate effective solutions for the case study system.

Keywords: *Simulation, lean manufacturing, value stream mapping, WITNESS, case study.*

1.0 INTRODUCTION

In the manufacturing world, the most important thing to be considered is the finished product that fulfilled the criteria needed in order to strengthen the business and fulfil the customers' requirement. In this study, student is applying Lean Manufacturing using Value Stream Mapping and simulation in an auto-parts manufacturing company. This study seeks to improve the productivity of the manufacturing company by constructing the value stream mapping which aids in the development of a "current state map" that shows a visual representation of how the company is currently operating. After that, a simulation model which imitates a real production system based on the information from the value stream map will be designed using Witness software to be run and validated.

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The main products made by this company are electro mechanical products and Printed Circuit Board (PCB) Assembly products. Although this company has applied the lean manufacturing using value stream map in their plant, they applied only at the selected

workstations which have problems. In this study, student will apply this quality tool to all workstations in the plant.

The objectives of this study are to demonstrate the process of implementing two techniques, value stream mapping (VSM) and computer simulation. VSM is used to portray the current state of the production system so that areas for efficiency improvements can be identified and alternatives for improvement can be formulated. Computer simulation technique is applied to imitate the real production system through a mathematical/logical model so that all proposed solutions can be properly evaluated without interrupting actual production. A brief background of the company is given in the following section, followed by the statement of the case study.

2.0 Literature Riview

2.1 Lean Manufacturing

Lean manufacturing (LM) is an applied methodology of scientific, objective techniques that cause work tasks in a process to be performed with minimum of non-value adding activities resulting in greatly reduced wait time, queue time, move time, administrative time, and other delays.

The objective of LM is to reduce waste in every part (such as human effort, inventory, time to market and manufacturing space) to become more responsive to customer demand while producing quality products in the most efficient and economical manner (Womack et al., 1990). Besides that, this approach also focused in reducing the cost by eliminating non-value added activities. Applications of LM have spanned many sectors including automotive, electronics, white goods, and consumer products manufacturing.

2.2 VSM

A value stream is a collection of all actions (value added as well as non-value-added) that are required to bring a product (or a group of products that use the same resources) through the main flows, starting with raw material and ending with the customer (Rother and Shook, 1999). These actions consider the flow of both information and materials within the overall supply chain. Value stream mapping (VSM) acts as one of the enterprise improvement tools in LM. The ultimate goal of VSM is to identify all types of waste in the value stream and to take steps to try and eliminate these (Rother and Shook, 1999). Besides that, VSM creates a common basis for the production process, thus facilitating more thoughtful decisions to improve the value stream (McDonald et al., 2002). Value Stream Maps are a very effective method for summarizing, presenting and communicating the key features of a process within an organization (Taylor, 2005). The first step is to choose a particular product or product family as the target for improvement. The next step is to draw a current state map that is essentially a snapshot capturing how things are currently being done.

This is accomplished while walking along the actual process, and provides one with a basis for analyzing the system and identifying its weaknesses.

2.3 Simulation

Simulation is defined as the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behaviour of the system and/or evaluating various strategies for the operation of the system (Pegden et al., 1990). In Van Landeghem and Debuf (1997), Van Landeghem (1998), McDonald et al. 2000, 2002 and Rahn (2001), simulation is used to model manufacturing processes for a core product family and to validate the current supply chain map (or Current State map) as well as evaluating alternative scenarios.

The present-day production and manufacturing industries make use of computer simulation to take account of the complexities and dynamic changes within the production environment, whereby it has been adopted and emerged as an advanced, sophisticated, and flexible management analysis tool (Rotab Khan, 1999). It imitates and analyses the stochastic behaviours of the production system to determine its performance with a vision to assist the management in finding the best decision after evaluating various alternative results obtained from the simulation.

2.4 WITNESS Simulation Software

WITNESS simulation software permits its users to construct a computer model of virtually any existing or proposed process, simulate its functions, and analyze its performance. WITNESS is a Lanner Group’s simulation package. It is the culmination of more than a decade’s development experience with computer-based simulation. This experience has led us to evolve a visual, interactive and interpretative approach to simulation without the need for compilation. WITNESS provides the power to model virtually any working environment and inexpensively evaluate alternative approaches quickly and easily from the evaluation of a new production layout to the reengineering of an entire business process.

3.0 Methodology

The first method used to gain the data was observation. Observation on the manufacturing process flow is very important as the student need to design the current value stream mapping and simulation of the production line. Besides that, it is done to identify the main problem. By this, we could validate the problematic workstation shown by the simulation with the observed ones. Other than that, interviews are conducted with the manager and the manufacturing engineers in order to get the relevant data.

3.1 Case study’s background and problem statement

This automotive components company has 2 operation plants with both the building area of 6500sqm. Plant 1 is for productions of instrument display (ID) of vehicles. Besides, mechanical based products are also from manufactured in this plant. Plant 2, which has been chosen for this study, is a place produces electronic based productions for vehicles, which is Electronic Parking Brake (EPB).

This company applied VSM only at the selected workstations which have problems. In this study, student will apply this quality tool to all workstations in the plant. By doing this, problems detected could be solved.

3.2 Current VSM

All data for the current value stream mapping were collected after several observations and interviews are made with the related personnel. Figure 1 shows the current value stream mapping constructed; the small box in the map represents the process.

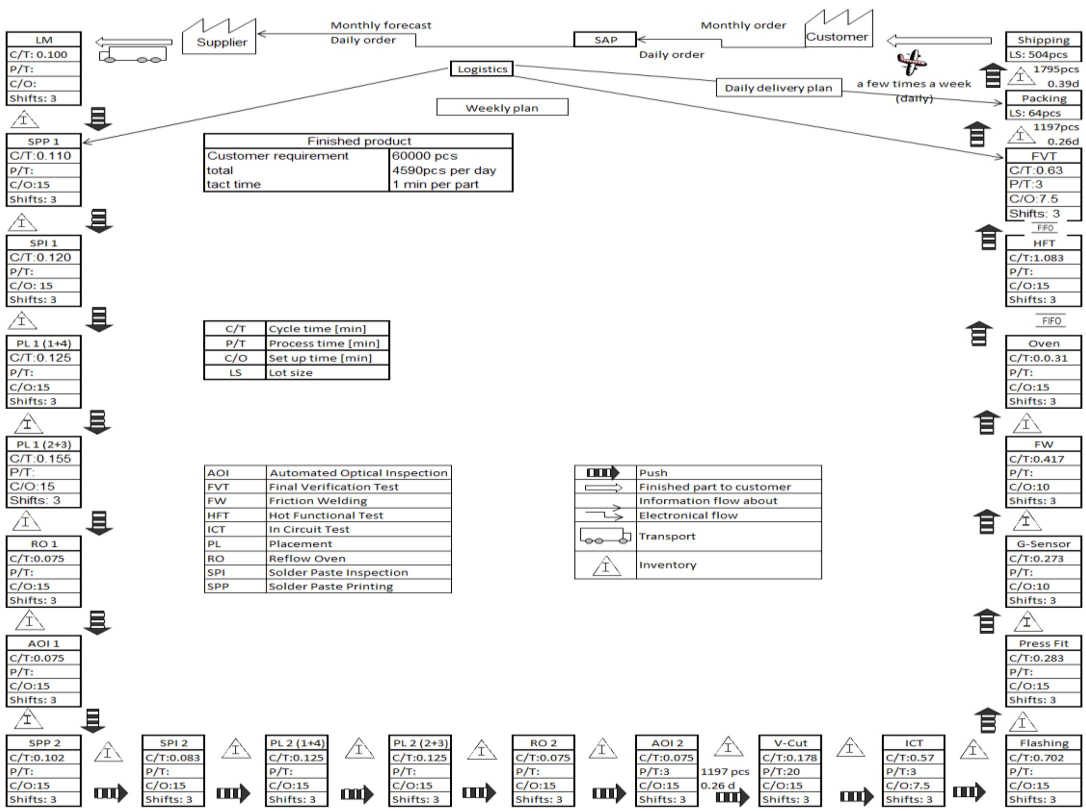

Figure 1 Current Value Stream Mapping

The current state map starts with customers placing daily orders that are transferred to a weekly production plan which the process supervisor must manage accordingly.

Note that not all workstations has inventory. Inventory only presents after the process of SMD line, final verification test and packing. This is because at certain workstation, the product needs to undergo the next process immediately in order to maintain their quality. As an example, after the product go through the Oven, it needs to be installed in Hot Functional Test (HFT) machine immediately because the test of HFT can only be run when the part is at high temperature. Thus, there is no inventory at the workstation. The symbol FIFO in the map represents First In First Out. The first part entering a machine will be the first part to enter the next machine.

Besides that, there is no inventory between ICT and Flashing although both machines have high cycle time. After ICT process, the operator in charge will directly place the product in Flashing machine for the installation of programming software. The standard time recorded for back-end machines has been added with 15% of allowance because they involve manpower.

Based on the data given, the lead time for the inventory is 0.91 day; this is calculated by dividing the inventory at each workstation by 4590 (daily average demand rate for the product.

3.3 Current simulation model

All the data required to build the simulation model are based on the data shown in the current value stream mapping. Simulation model is created by using the WITNESS simulation software which is commonly used for study purpose. Since the simulation model is the imitation of the real production flow, the output result produced should be as near as possible to the actual ones. If not, the simulation is not valid.

In this study, we focused on applying the quality tools on the process flow of the manufacturing company. Thus, we need to make the good changes on the production line in order to increase the current production efficiency. However, doing this on the actual process will cause money and worse, affect the productivity if the changes made are failed. With the use of the simulation, we could make any proposed changes theoretically without causing any cost.

In this simulation, the blue coloured icon indicates the machines. The yellow coloured box next to the machine represents the mode of the machine. At this coloured stage, the machine is waiting the part to be processed. Purple box shows the machine is blocked.

The product chosen to be simulated is EPB4PA which symbolized as part PCB. This is because, the first raw material used to make all products in the manufacturing company is printed circuit board (PCB). The simulation shows the actual process of making EPB4PA.

At the back-end processes (ICT – FVT), most of the workstations used to process the product have more than one machine. This is because the company would like to ensure the smoothness of the process flow. Besides that, there are work-in-progress (WIP) icon placed after AOI2, V-Cut and Flashing. The WIP symbolize that the products are waiting because the next machine is in use for different batch.

The icon OutputEPB4PA is a variable that will show the total number of PCB produced for a given time. The simulation will be running for 450 minutes (1 shift), 1,350 minutes (1 day), 7,762.5 minutes (1 week) and 31,050 minutes (1 month).

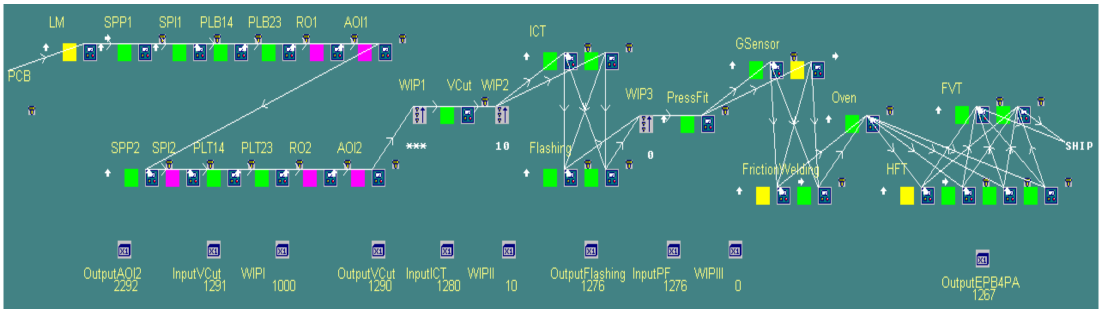

Figure 2 Current simulation model after running for 1 shift

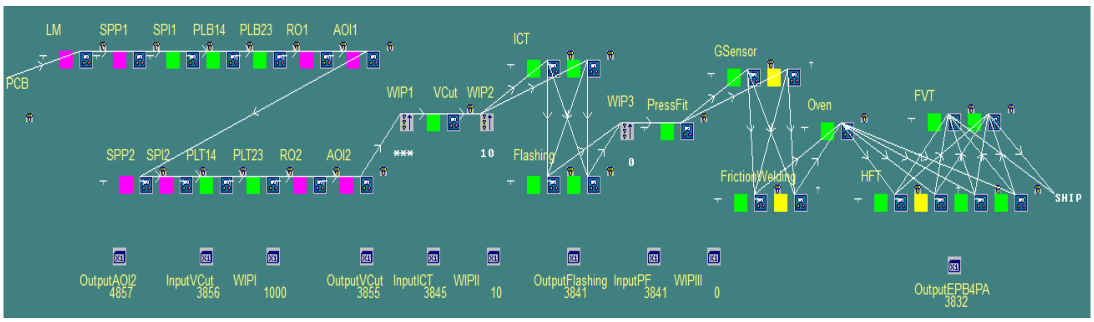

Figure 3 Current simulation model after running for 1 day

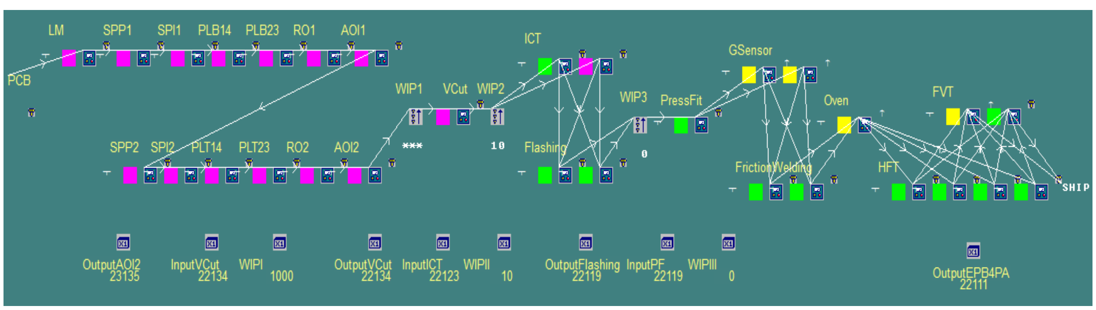

Figure 4 Current simulation model after running for 1 week

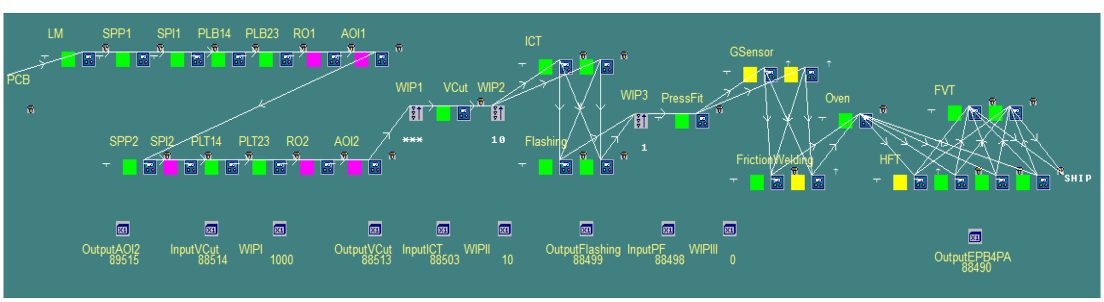

Figure 5 Current simulation model after running for 1 month

Table 1 Model Verification

Run	Simulation Result	Actual Result	Efficiency (%)
	Output (pcs)	Output (pcs)	Output
Simulation 1 (1 shift = 7.5 hours)	1267	1530	82.81
Simulation 2 (1 day = 22.5 hours)	3832	4590	83.50
Simulation 3 (1 week = 129.4 hours)	22,111	26,392	83.78
Simulation 4 (1 month = 517.5 hours)	88,490	105,570	83.82

4. Development of Alternative Solutions

Table 2 shows the analysis of the current simulation model summarized by the WITNESS Simulation System. This is one of the advantages of using the simulation system.

From the table, we could identify several important factors, such as, the percentage of idle, percentage of busy and total number of operations for each machine. There are two methods that will be used to optimize the production line:

i. Reduce the machine that has the highest percentage of idle
ii. Add more machines to the workstation that has the highest percentage of busy.

Both of the improvement methods are applied by altering the current simulation model. The results regarding the total output of finished product processed by the alternative solution will be discussed below. These results will determine whether the alternatives can be considered to be used or not. Based on the table, the highest percentage of idle is G-Sensor2, which is 100%, which also indicate that the number of operation is zero. This shows that the presence of the second G-Sensor could be eliminated. The elimination could reduce some cost especially the labor and operator cost.

The highest percentage of busy shown in the table is Flashing 1 and Flashing 2 which is 99.56% and 99.53% respectively. In terms of number of operations, the machines have run about 600 operations. The placement of Flashing 3 possibly could increase the production efficiency and increase the total finished products.

Table 2 Analysis Data for Current Simulation

Name	Process	% Idle	% Busy
LM	Laser Marking	30.44	49.78
SPP1	Solder Paste Printing 1	21.5	54.72
SPI1	Solder Paste Inspection 1	16.67	59.67

PLB14	Placement 1(1+4)	10.6	62.14
PLB23	Placement 1 (2+3)	4.8	77.01
RO1	Reflow Oven 1	37.08	37.26
AOI1	Automated Optical Inspection 1	37.08	37.24
SPP2	Solder Paste Printing 2	26.33	50.44
SPI2	Solder Paste Inspection 2	33.67	41.36
PLT14	Placement 2 (1+4)	16.94	61.96
PLT23	Placement 2 (2+3)	16.97	61.93
RO2	Reflow Oven 2	37.04	37.17
AOI2	Automated Optical Inspection 2	37.07	37.12
Vcut	V-Cut	0.28	51.1
ICT(1)	In Circuit Test	0.32	81
ICT(2)	In Circuit Test	0.36	81
Flashing(1)	Flash Programming	0.44	99.56
Flashing(2)	Flash Programming	0.47	99.53
PressFit	Press Fit	19.73	80.27
Gsensor	G-Sensor	22.57	77.43
Gsensor	G-Sensor	100	0
FrictionWelding(1)	Friction Welding	41.01	58.99
FrictionWelding(2)	Friction Welding	37.3	58.94
Oven	Oven	12.32	87.63
HFT(1)	Hot Functional Test	23.44	76.56
HFT(2)	Hot Functional Test	23.51	76.49
HFT(3)	Hot Functional Test	23.6	76.40
HFT(4)	Hot Functional Test	23.67	76.33
FVT(1)	Final Verification Test	11.24	88.76
FVT(2)	Final Verification Test	11.29	88.71

4.1 Alternative Solution 1: Eliminate idle machine

Alternative solution 1 is the reduction of the number of G-Sensor. In the current production line, the number of G-Sensor machines is two. For this alternative solution, we will reduce the total number of G-Sensor into one only since the

analysis shows that one of them is completely idle. Idle movement is one of the wastes. Thus, the reduction of waste shows that we have achieved the objective of lean manufacturing.

The alternative simulation is run for 450 minutes (1 shift) and 1350 minutes (1 day).

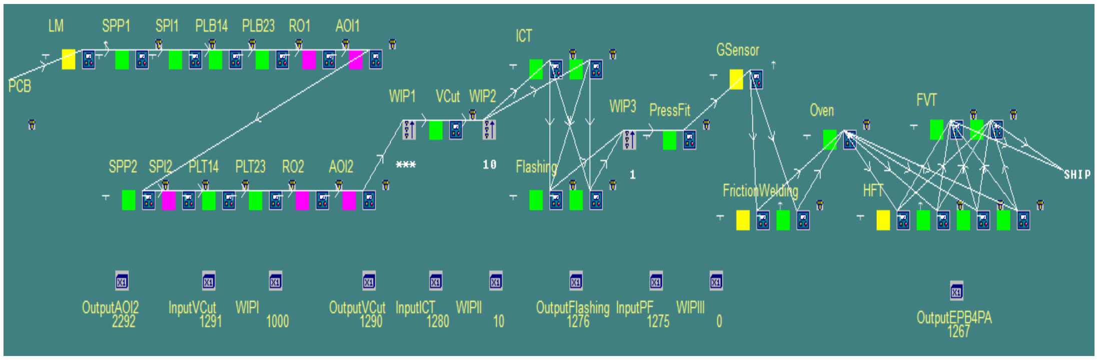

Figure 6 Alternative solution 1 after running for 1 shift

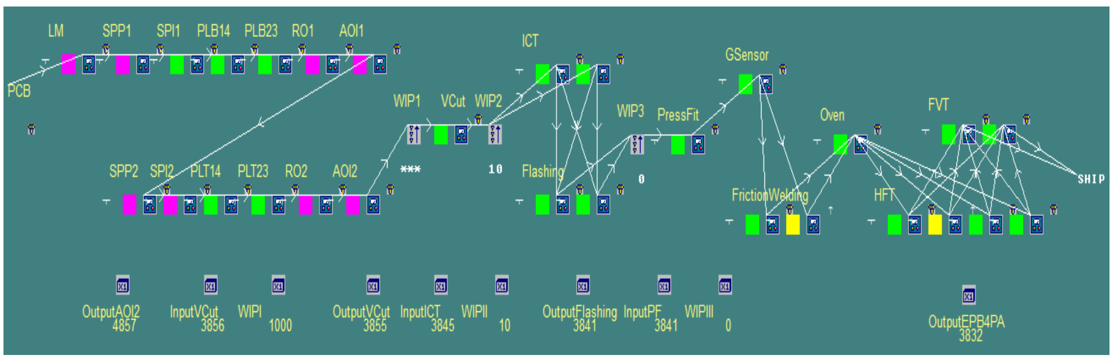

Figure 7 Alternative simulation 1 after running for 1 day

Table 3 Result for Alternative Solution 1

Alternative	Output				Improvement (%)	
	Shift		Daily			
	Before	After	Before	After	Shift	Daily
Alternative Solution 1	1267	1267	3832	3832	0	0

Name	Process	% Idle	% Busy
LM	Laser Marking	31.58	51.18
SPP1	Solder Paste Printing 1	22.94	56.29
SPI1	Solder Paste Inspection 1	18.00	61.38
PLB14	Placement 1(1+4)	11.31	63.92
PLB23	Placement 1 (2+3)	5.12	79.21
RO1	Reflow Oven 1	39.55	38.33
AOI1	Automated Optical Inspection 1	39.55	38.3
SPP2	Solder Paste Printing 2	28.09	51.88
SPI2	Solder Paste Inspection 2	35.91	42.54
PLT14	Placement 2 (1+4)	18.07	63.73
PLT23	Placement 2 (2+3)	18.1	63.69
RO2	Reflow Oven 2	39.51	38.23
AOI2	Automated Optical Inspection 2	39.54	38.17
Vcut	V-Cut	0.30	51.14
ICT(1)	In Circuit Test	0.34	80.99
ICT(2)	In Circuit Test	0.38	80.97
Flashing(1)	Flash Programming	0.47	99.53
Flashing(2)	Flash Programming	0.51	99.49
PressFit	Press Fit	19.73	80.27
Gsensor	G-Sensor	22.62	77.38
FrictionWelding(1)	Friction Welding	41.03	59.97
FrictionWelding(2)	Friction Welding	37.32	58.92
Oven	Oven	12.37	87.63
HFT(1)	Hot Functional Test	23.44	76.56
HFT(2)	Hot Functional Test	23.51	76.49
HFT(3)	Hot Functional Test	23.6	76.40
HFT(4)	Hot Functional Test	23.67	76.33
FVT(1)	Final Verification Test	11.24	88.76
FVT(2)	Final Verification Test	11.29	88.71

Table 4 Analysis Data for Alternative Solution 1

4.2 Alternative Solution 2: Reduce the number of operators at selected machines

Alternative solution 2 is the reduction of the number of operators. Based on the observation, the process for ICT machine and Flashing machine could be done by the same operator. This is because the processing time for ICT and Flashing is longer than other machines. Thus, the operator could operate the Flashing machine when the ICT machine is processing the EPB4 PA and vice versa. Besides that, HFT machines also required a long time to process the product. Therefore, just like the ICT and Flashing machines, these machines could also be conducted by 2 operators instead of 4 operators.

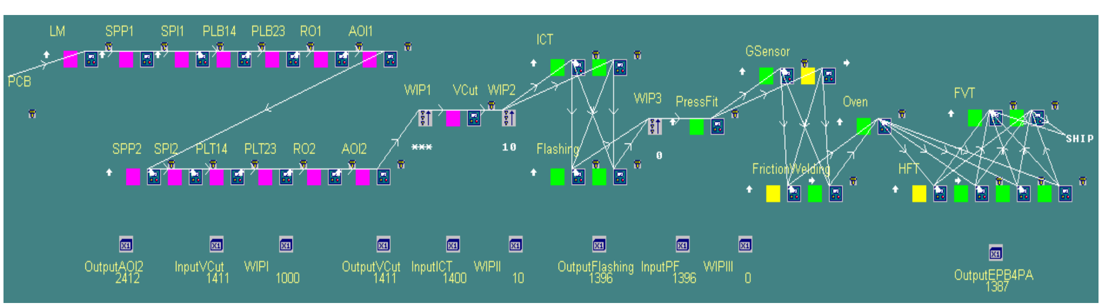

Figure 8 Alternative solution 2 after running for 1 shift

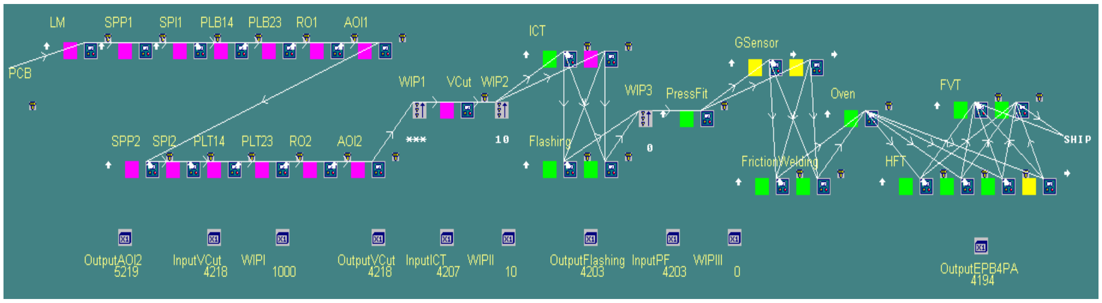

Figure 9 Alternative solution 2 after running for 1 day

Table 5 Result for Alternative Solution 2

Alternative	Output				Improvement (%)	
	Shift		Daily			
	Before	After	Before	After	Shift	Daily
Alternative Solution 2	1267	1387	3832	4194	9.47	9.45

4.3 Alternative Solution 3: Alternative 1 + Alternative 2

Alternative solution 3 is the combination of the alternative 1 and alternative 2, which are the reduction of G-Sensor machine and the reduction of operators' numbers at ICT, Flashing and HFT machines.

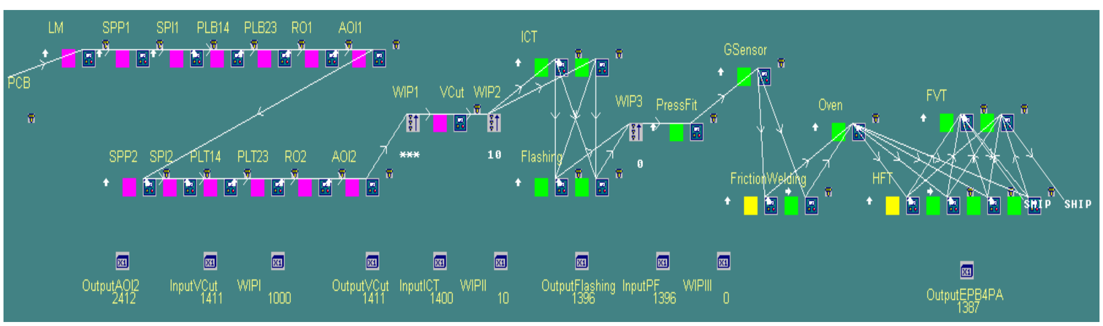

Figure 10 Alternative solution 3 after running for 1 shift

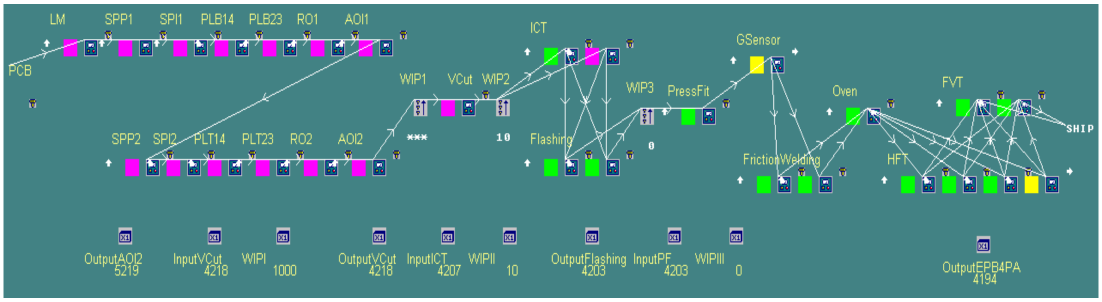

Figure 11 Alternative solution 3 after running for 1 day

Table 6 Result for Alternative Solution 3

Alternative	Output				Improvement (%)	
	Shift		Daily			
	Before	After	Before	After	Shift	Daily
Alternative Solution 1	1352	1387	3832	4194	9.47	9.45

Table 7 Analysis Data for Alternative Solution 3

Name	Process	% Idle	% Busy
LM	Laser Marking	21.59	38.73
SPP1	Solder Paste Printing 1	8.31	42.61
SPI1	Solder Paste Inspection 1	6.50	46.48
PLB14	Placement 1(1+4)	4.05	48.42
PLB23	Placement 1 (2+3)	1.81	60.01
RO1	Reflow Oven 1	14.33	29.04
AOI1	Automated Optical Inspection 1	14.34	29.03
SPP2	Solder Paste Printing 2	10.17	39.34
SPI2	Solder Paste Inspection 2	13.01	32.25
PLT14	Placement 2 (1+4)	6.52	48.35
PLT23	Placement 2 (2+3)	6.53	48.32
RO2	Reflow Oven 2	14.31	29.01
AOI2	Automated Optical Inspection 2	14.32	28.98
Vcut	V-Cut	0.10	55.72
ICT(1)	In Circuit Test	0.11	81.15
ICT(2)	In Circuit Test	0.13	81.13
Flashing(1)	Flash Programming	0.15	99.85
Flashing(2)	Flash Programming	0.16	99.84
PressFit	Press Fit	11.79	88.21

Gsensor	G-Sensor	14.93	85.07
FrictionWelding(1)	Friction Welding	35.17	64.83
FrictionWelding(2)	Friction Welding	31.06	64.82
Oven	Oven	3.56	96.44
HFT(1)	Hot Functional Test	23.01	76.99
HFT(2)	Hot Functional Test	23.51	76.49
HFT(3)	Hot Functional Test	23.6	76.40
HFT(4)	Hot Functional Test	23.67	76.33
FVT(1)	Final Verification Test	2.1	97.9
FVT(2)	Final Verification Test	2.12	97.88

Table 8 Result for all Alternatives Simulation

Alternative	Output				Improvement (%)	
	Shift		Daily			
	Before	After	Before	After	Shift	Daily
Alternative Solution 1	1267	1267	3832	3832	0	0
Alternative Solution 2	1267	1387	3832	4194	9.47	9.45
Alternative Solution 3	1267	1387	3832	4194	9.47	9.45

5. Analysis and Discussion

5.1 Analysis of alternative solutions

There are three alternatives developed for the purpose of finding the best solutions with regards to the performance measurement. The most important element to be considered in determining the best solution is the total output of finished products produced by each solution. The output of the selected alternative should be the one that producing the highest value of finished product. As mention earlier, our aim is to increase the production efficiency and reduce waste which means reducing the cost too.

Based on Table 8, the efficiency of the production is obtained by dividing the total output produced in the alternative simulation with the current simulation output. The value of the efficiency obtained is the value of improvement made.

It can be seen from Table 8 that the output for Alternative 1 is the same as the current simulation output. This is because we eliminate the idle machine, which is G-Sensor because it does not give any benefit to the production line other than waste. Therefore, the elimination does not affect the value of the output.

Besides that, based on Figure 12, Alternative 2 and Alternative 3 show a significant increase in the total output. Alternative 2 is the reduction of operators' number. The reduction takes place at the ICT, Flashing and HFT machine. This is because the processing time of the machines are high, causing the operator in charge of the machine to be idle. Therefore, student made the ICT and Flashing machine to be run by an operator only instead of two operators, whereas, as for HFT, an operator will be in charge of 2 HFT machines at the same time. Alternative 3 is the combination of Alternative 1 and Alternative 2. Alternative 2 and Alternative 3 shows the same output value. Alternative 3 is considered as the best solution.

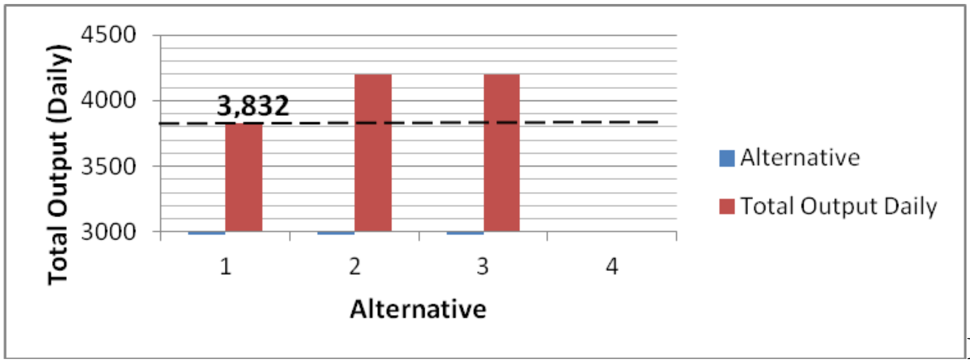

Figure 12
Total Output Vs Alternative

5.2 Selecting the Best Alternative Solution

The performance measurement uses three criteria, which is the total output, percentage of improvement and the reduction in waste. In order to find the best solution among all alternatives, weightage is given to both criteria. The weightage that will be given is 60% for the total output, 20% for the improvement and 20% for the waste reduction. The total output is given with the highest weightage because it is the most considered and important criteria compared to other criteria.

The alternative that can produce the output more than the output of the actual simulation will be given the full marks which are 60/60, while the alternative that produce equal or less will get 0/60. As for the improvement, the highest improvement will receive 20/20, and 0/20 for the lowest percentage of improvement. 20/20 will be given to alternative that could reduce waste and 0/20 to those that have no reduction.

Criteria	Description
1	Total Output
2	Percentage of Improvement
3	Waste Reduction

Table 9 Criteria Considered

Criteria	Level	Weightage (%)	Total (%)
1	High	60	60
	Low	0	
2	High	20	20
	Low	0	
3	Yes	20	20
	No	0	

Table 10 Description of Weightage

Simulation Model	Criteria 1 (/60%)	Criteria 2 (/20%)	Criteria 3 (/20%)	Final Score (%)
Alternative 1	0	0	20	20
Alternative 2	60	20	0	80
Alternative 3	60	20	20	100

Table 11 Final Score for each Alternative

Alternative 3 which is the combination of Alternative 1 and Alternative 2 shows the best score in Table 11. Alternative 3 which is the elimination of idle G-Sensor machine and reduction the number of operator at ICT, Flashing and HFT machines give the best score with 90%, followed by Alternative 2 and Alternative 1. Therefore, Alternative 3 is chosen as the final alternative solution.

6. Conclusion and Further Research

This study was conducted at a manufacturing company that producing Electronic Parking Brake (EPB) which based in Perai, Penang. The product selected for this study is EPB 4PA, a device created for an international brand car. Current VSM is designed to replicate the flow of the production line. Then, a simulation is built based on the information stated in current VSM by using WITNESS to imitate the current production flow. Several alternative solution models have been simulated using WITNESS for the purpose of increasing the efficiency of the production.

A total of three alternatives were modelled by the software and after measuring their performance measurement, Alternative 3 gave the best score. The performance measured is the total output, percentage of improvement and waste reduction. All criteria were fully scored by Alternative 3 causing it to get the highest marks.

As a whole, Alternative 3, if applied, manage to increase the output from 1267 pieces to 1387 pieces in one shift, and from 3832 pieces to 4194 pieces a day, increased in improvement by 9.47% from current simulation and reducing the waste given by idle machine.

As a conclusion, the objective of this study has been achieved. The application of Lean Manufacturing through Value Stream Mapping and simulation is succeed.

Some focal points of future research will be:

1. The simulation is not limit to a product only; instead it could be replicated for many products.
2. All products in this study are assumed as passed, although some of them are rejected. It is better to consider the rejected parts too to increase the efficiency of the data.
3. The data exclude in this study are setup time, changeover time and breakdown time due to time constraint. The presence of these data could increase the accuracy of the simulations.

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