© Universiti Tun Hussein Onn Malaysia Publisher's Office

JSMT

http://publisher.uthm.edu.my/ojs/index.php/jsmt

e-ISSN : 2821-2835

Journal of Sustainable and Manufacturing in Transportation

Implementation of Lean Manufacturing to Improve Production Efficiency: A Case Study of Electrical and Electronic Company in Malaysia

Jeevan Ganesan[1], S Kanna Subramaniyan[1,2*], Mohd Rasidi Ibrahim[1], Ho Fu Haw[1]

[1]Faculty of Mechanical and Manufacturing Engineering,
Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, 86400, MALAYSIA

[2]Crashworthiness and Collisions Research Group, Faculty of Mechanical and Manufacturing Engineering,
Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, 86400, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/jsmt.2023.03.02.006
Received 14 December 2023; Accepted 04 February 2024; Available online 31 December 2023

Abstract: The manufacturing industry plays a crucial role in the economy development of a country includes Malaysia. Lean manufacturing is a production method that aims to minimize waste and optimize efficiency in the manufacturing process. By applying lean manufacturing, it enables a company to pursues continuous improvement and integration of labor with a clear focus on value adding activities and elimination of waste. However, this concept is still not widely being applied by all type of company or limited in certain aspects only. This study aims to implement lean concept into a medium sized electronic company in Malaysia named as Company ABC, particularly to improve the efficiency of the production line. Company ABC is expanding its production line, thus looking forward to implement 8 Waste and VSM to improve the Line Balancing Rate and improve the line productivity from 1500 units/ week to 3000 units / week. The clarifications lead to this study is to understand, how the Implementation of Lean Manufacturing can help to improve the production line efficiency, what are the factors that causes producibility issues during design development stage and what are the area of improvement of the manufacturing line of Model X that could be enhanced and applied in this particular project. The goal of this study is to assess the contribution of Lean six sigma in the company to increase the process line productivity and maximize the efficiency of the production process. A model was developed to simulate the efficiency improvement of the production line after application of Lean Manufacturing.

Keywords: Line balancing, lean manufacturing, six sigmas, production efficiency

1. Introduction

Lean manufacturing is a production method that aims to minimize waste and optimize efficiency in the manufacturing process [1]. Lean manufacturing, a system that pursues continuous improvement and integration of labor with a clear focus on value adding activities and elimination of waste, has been widely recognized and accepted in manufacturing [2]. It is based on the idea of continuous improvement and is focused on eliminating waste in all forms, including overproduction, unnecessary inventory, unnecessary motion, and defects. In lean manufacturing, the goal is to create value for the customer by producing products with the highest quality, in the shortest amount of time, and with the least number of resources. Existing research is on application of lean manufacturing are general on the application

**Corresponding author: skanna@uthm.edu.my*

on an industry with one lean method to measure on the success rate in an applied industry. This is achieved by identifying and eliminating waste in the production process, streamlining operations, and continuously improving the efficiency of the manufacturing process. Some of the key principles of lean manufacturing include the identification and elimination of waste, the optimization of the flow of materials and information, and the empowerment of employees to continuously improve the production process [3].

Lean manufacturing has been successfully implemented in a wide range of industries and has been shown to increase efficiency, reduce costs, and improve customer satisfaction. Lean manufacturing emphasizes continuous improvement and the identification and elimination of defects, which can lead to higher quality products [4]. By producing high-quality products in a timely manner, lean manufacturing can help increase customer satisfaction. By reducing costs and increasing efficiency, lean manufacturing can help a company gain a competitive advantage in the marketplace. Overall, lean manufacturing can help a manufacturing company improve its performance and competitiveness in the marketplace. The main problem faced by Manufacturing Companies is that the efficiency of the line is not maximized to have the maximized output. The efficiency of the line can be measured by measuring two important criteria that are the Line Balancing rate (LBR) and Operator Utilization Rate. In an approach to continuously improving this, Industries tends to adopt Lean Manufacturing as a method to drive Continuous Improvements in the manufacturing Line.

There are several reasons why manufacturing companies may want to apply lean manufacturing methods. For example, Lean manufacturing can help reduce costs by eliminating waste and optimizing the production process [5]. This can result in lower production costs and higher profits. Lean manufacturing aims to optimize the flow of materials and information, which can help increase efficiency and reduce lead times. This project will be concentrating on usage of Value Stream Mapping and 8 Waste to demonstrate the improved efficiency of a production line. The improvements gained by the Company in implementing Lean Manufacturing can be measured by comparing the output of the manufacturing line before and after the improvements. Manufacturing company can be divided into two that is Original Equipment Manufacturer (OEM) and Contract Manufacturing (CM).

In this study, a contract based company is selected. Contract manufacturing is a type of manufacturing in which a company outsources the production of certain components or products to another company. The company that provides the manufacturing services is known as the contract manufacturer, while the company that contracts the work out is known as the original equipment manufacturer (OEM). Contract manufacturing can be used to produce a wide range of products, including electronics, automotive parts, medical devices, and consumer goods. A successful CM often adopt few methodologies in the production line that are Six Sigma method and Lean Manufacturing to improve the quality and the line efficiency for maximized output and revenue. The research of this paper will concentrate more on applying a few principles from lean such as VSM and 8 Waste to improve the Line Balancing Rate and improving the Operator Utilization Rate thus increasing the output of the line. The objectives of this paper will be to assess the contributions of Lean six sigma to process line in the company, to increase the process line productivity and maximize the efficiency of the production process, develop a model to simulate the efficiency improvement of the production line after application of Lean six sigma method.

2. Methodology

2.1 The 8 Waste Methodology

In lean manufacturing, waste is defined as any activity or process that does not add value for the customer. There are eight types of waste that are commonly identified in manufacturing environments, known as the "8 Wastes" (refer Fig. 1 below). These waste are [6]

i. Overproduction: Producing more than is needed or producing before it is needed.
ii. Waiting: Time spent waiting for materials, equipment, or instructions.
iii. Defects: Errors or mistakes that require rework or scrap.
iv. Excess inventory: Having more raw materials, work-in-progress, or finished goods than necessary.
v. Unnecessary motion: Extra movement or handling of materials that does not add value.
vi. Unnecessary processing: Performing unnecessary steps or using unnecessary equipment in the production process.
vii. Unused talent: Underutilizing the skills and expertise of employees.
viii. Transport: Moving materials or products unnecessarily or inefficiently.

In this study, identifying and eliminating these wastes is a key aspect of lean manufacturing, as it helps to reduce costs, improve efficiency, and increase customer satisfaction (refer Table 1 below). To identify waste, manufacturers can use tools such as value stream mapping and kaizen events, which involve bringing together cross-functional teams to analyze and improve processes.

Once waste has been identified, it can be eliminated through a variety of methods, such as automating processes, standardizing work, implementing pull systems, and using poka-yoke (error-proofing) devices. By reducing or eliminating these wastes, manufacturers can improve the efficiency of their production processes and produce high-quality products with minimal waste and lead time.

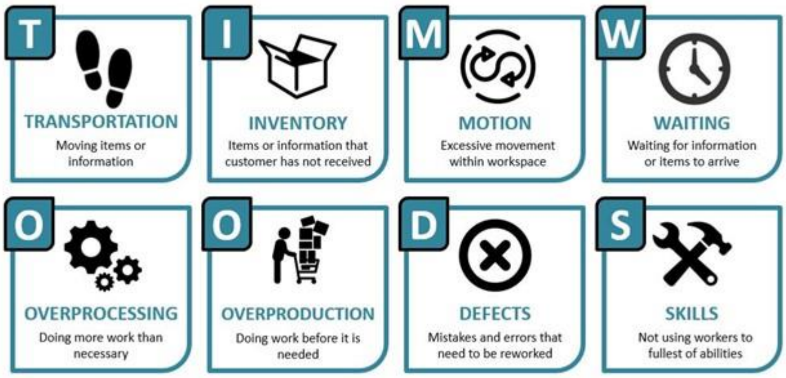

Fig. 1 - The 8 wastes elements [1]

Table 1 - 8 Waste improvements in the production line

Methodology	Improvements applied in Manufacturing Line
Transportation	Reduction of MES manual scanning and introduce auto scanning method to reduce manual scan time by operators Implementation of AGV units to move the materials from Kitting to Production Floor.
Inventory	Remove all the in-process kanban in the station to remove WIP buildup Increase the capacity of trolleys to hold larger quantity of materials
Motion	Introduce inline curing station for 30mins to eliminate operator handling and movement to move the units to the curing trolley Improve the machine movement speed to improve CT to prevent adding additional machine
Waiting	Improve the Line Balancing rate of the production line from 46% to 80% to reduce operator waiting time
Overprocessing	No Improvement done
Overproduction	Improve the line to be in Single Piece Flow to prevent WIP accumulation and remove all the trolleys in the production floor.
Defects	No Improvement done
Skills	No Improvement done

2.2 Visual Stream Mapping (VSM) Methodology

Analysis from VSM has indicated that some stations needed to be duplicated or split the processes in order to improve the CT. 8 Waste could not be applied in these stations because there were 1 test station in which the testing time is fixed and motion improvement in unit handling will not give a significant impact to the process Cycle Time. Another 3 stations which is highlighted in the VSM is a critical process that needs handling in fine wires which require adjustment and placement of the wires in the unit. One of the major problems faced was with the space available for station to be added. The goal is to minimize the insertion of workstations to prevent line to be longer. This approach uses same space consumption but requires addition headcount to perform testing on the rear side of the line. The CT improvement has been cut into half due to this activity thus meeting the new targeted Takt time.

3. Case Study Background

3.1 Selection of Industry for Case Study

A company in Batu Kawan, Penang (named as Company ABC), which is a Contract Manufacturing having difficulties to fulfill customer satisfaction in one of the products manufacturing (Model X) as to the requirements from the Customer are varied according to the demand of the product from the Customer.

The Model X production line was requested to have a dedicated line to prevent mixture of models. During the line design stage, the demand was at 1500 units / week thus Company ABC had to design a line that can produce 1500 output / week with minimum HC used, minimum number of workstations and smallest line layout dimension. After initial designing stage, the line was designed with 24HC, 24 Manual Workstation and 2 Automated Stations with 1050 sq.ft. The line has been qualified to produce 1500 units/ week and Customer has increased the demand to 3000 units / week.

Company ABC had to expand the production line into 2 lines to be able to cater the demand from the Customer, with 24HC and 1050 sq.ft. The cost of 1 HC is calculated as USD $1000 and the cost of rental of 1 sq. ft is estimated at USD $3.62/sq.ft. The total cost beared by Company ABC was USD $51,401/month for setting up the second line. However, there has been fluctuations in Customer demand with WK1 = 1500, WK2 = 2000, WK3 = 1700, WK4 = 2100, WK5 = 3000. The fluctuations in the demand have caused operator utilization rate of operators to be reduced and as a Contract Manufacturing, this is not good for the revenue of the Company.

To eliminate the wastages in HC and Space, Company A has decided to apply Lean Six Sigma methodology and Continuous Improvement to improve 1-line capacity from 1500 units / week to 3000 units / week while maintaining the Number of HC and maintaining the floor space The improvement done with save 24 HC / shift which is equivalent to 48 HC for 2 shifts that will cost about USD $48,000 and space savings of 1050 sq. ft equivalent to USD $3801. Savings in floor space can enable Company A to bring in other model manufacturing line thus the increase in revenue would be higher.

3.2 Data Collection

The information regarding the company was collected from the company to be used for developing the model. The information needed was obtained by two methods that are by interviewing the engineer of the production floor and by documentation provided by the company. A more efficient way of gathering information was the videotaping method but camera usage was prohibited in the company compound hence videos were not taken.

Several parameters were collected to implement VSM and 8 Waste. The complete information on the company is needed for efficiently building the model. Information needed were:

a) Documentation of customer information - The complete information on the work order, quantity and lead time is needed in order to compute the job procedure and delivering time.
b) Documentation of supplier information - The information on the material supply needed in order to calculate the amount of material sufficiency.
c) Data collection of cycle time, lead time and current changeover time - This information is vital to calculate the total time needed for printing the plastic for specified quantity.
d) Process flow - The information on the total process flow will be required for steps needed to be done before the printing process. The type of machine and tooling and the total station that the product needs to pass.
e) Labor information - a complete information on the expert workers and total workers list are needed.

3.3 Experimental Design

Model X production line was designed for manufacturing demand 1500units/week. The bottleneck of the manufacturing line is 210s. With 5 days working, 10.75hrs / shift and running total 10 shifts/week, the line can only produce up to 1800 units, the details of the production activities and cycle time is shown in Table 2 below.

Upon qualification and production run for 6 months, Customer has requested to increase the demand of Model X from 1500 units / week to 3000 units / week. To fulfill the requirements from the Customer, the management has decided to bring in 2nd line of the same setup to cater the double demand from Customer. This approach would increase the HC for the line up to 48HC and Space Utilization of 1050sq.ft. The cost of building up a line was calculated as USD$750,000 and monthly expenses of USD$51,300 to keep the line running. A study was initiated from the Engineering team to improve the output of Line 1 to 3000 units/week which can save Company ABC with the investments cost and additional monthly expenses. Lean Manufacturing method was implemented to make the improvements.

Table 2 - Process flow and cycle time of each station

Process	CT(Sec) with 15% Efficiency
MA1	192.05
Tim Machine	176
HLA 1 + Press	128
HLA 1A	150
Curing	100
MA3	94.3
HLA2	164.45
FVT 1	210
HLA 4	127

HLA 5	115
HLA 6	161
HLA 7	92
HLA 8A	207
HLA 9	149.5
HLA 10	103.5
FVT 2	65.55
FVT 3	86.25
FVT 4	158.01
HLA 11	135.7
FNI	128
OBA	128

3.4 Data Analysis

Takt Time for 3000units/week was calculated as (10.75hr/shift*3600s*5 working days* 2 shifts*85%) / (3000 units) = 129s. The efficiency was set at 85% PFD losses. 5% losses were calculated for Performance Loss, 5% were calculated for Fatigue Losses for Operators and 5% were calculated for Downtime losses for Automation and Conveyors. All the stations were targeted to have maximum Cycle Time of 129s. Visual Stream Mapping and 8 Waste analysis was used to study the Sequence of Events of the processes to optimize the Cycle Time and improve Line Balancing Rate of the Model X Production Line to maximize the efficiency of the line and improve the Operator Utilization Rate of the production line.

The stations which have higher cycle time than the Takt Time was identified for further improvement. Table 3 below shows all the stations that have higher CT compared to Takt Time. Upon identification, VSM was carried out for detailed analysis of the processes on the station.

3.4.1 Transportation Improvement

Manual scanning is defined to have 10 sec of additional time in the CT as it has several processes involved. The sequence of manual scanning will follow as, lifting up the scanner, scanning the s/n, click ok on the screen and placing back the scanner on the holder before moving to unit to the next station. Implementation of inline auto scanners has reduced these effects on CT thus improving the efficiency of the operators in the assembly station. Upon installations of the inline scanning, the CT improvement was calculated at 12.7% which improves the overall UPH of the line thus improving the overall output of the manufacturing line for the shift.

Another improvement with 8 waste concept in Transportation was for Raw material transport from Kitting area to the Production floor. Every line has been assigned with Material Handlers who are responsible to bring all the materials to ensure smooth production flow. They will ensure the timely replenishment of raw materials is reaching the production line and delivering the finished goods to pack out area to ensure no WIP buildup in the production floor. With increase of UPH from 15 to 30, the load on the Material Handlers will be high which will reduce the Efficiency of the Operators. To improve this, a suggestion was provided to deploy Automated Guided Vehicle (AGV) to carry out these works in scheduled time manner.

Table 3 - Bottleneck stations and proposed improvements

Process	Cycle Time	Proposed Improvement 1	Proposed Improvement 2
MA 1	192.05	Duplicate the station to use 2 operators. CT can be split into 2 that is 95.5s	Semi-Automatic Jig to improve the operator handling time and improve the process CT
TIM Machine	170	Purchase another machine and split the process	Reduce the gantry movement time and machine process time
HLA 1A	150	Split the process to use 2 operators CT can be split into 2 that is 75s	Reduce the scanning processes and manual handling movements by Operators. Utilize

			automated curing to minimize manual pallet handling by Operators.
HLA 2	164.45	Split the process to use 2 operators. CT can be split into 2 that is 83s	Merge the process with MA3
FVT 1	195.5	Split the process to use 2 operators. CT can be split into 2 that is 98s	Option 1 is the best option
HLA 6	161	Split the process to use 2 operators. CT can be split into 2 that is 81s.	Option 1 is the best option
HLA 8A	207	Split the process to use 2 operators CT can be split into 2 that is 104s.	Option 1 is the best option
HLA 9	149	Split the process to use 2 operators. CT can be split into 2 that is 75s	Improve the process and scanning process to reduce manual handling time
FVT4	158.01	Involve more testers to cater in the requirement	Option 1 is the best option
HLA 11	135.7	Split the process to use 2 operators. CT can be split into 2 that is 95.5s	Improve the process and scanning process to reduce manual handling time

3.4.2 Inventory Improvement

Increase in UPH will require increasing in material replenishment time. Increase in frequency of material replenishment will require having Headcount increase which will not meet the goal of the project. We have adapted Lean method to reduce the Inventory Trolleys and increased the capacity of the trolleys to hold double quantity of material. Double layer trolley which can hold 18 units of PCBA and Brackets gives great improvement in . This has maintained the replenishment time of the material thus does not require additional Headcount to manage the demand of the production line.

3.4.3 Motion Improvement

The requirement for the product is to have a curing of 40 mins prior going for testing station. This is to allow the chemical being applied would dry off before going to next stations. During the line setup, this process was added in as a request from Customer and a manual method had been implemented to move the units into a curing rock as shown in Figure 3.6. Two trolleys were placed to hold the units for 40 minutes before moving to next station. The manual movement of pallets into the trolley has several steps which can be improved to reduce the CT

The steps to move into the trolley

i. Scan the pallet for time control
ii. Transfer the barcode label from pallet to unit
iii. Carry the unit
iv. Turn 90 deg to clockwise
v. Place the unit on the trolley
vi. Turn 90 deg anti clockwise
vii. Resume the next unit

These activities have a huge impact on the CT as this is one of the bottleneck stations when the demand increases to 3000 units/ week. A solution was proposed to invest in Inline Curing where the steps mentioned above is not required to be done as all the steps can be automated which will have a huge improvement in the CT. Second improvement for motion was planned at TIM machine station with CT of 176s. The takt time was set at 134s to meet Customer demand. Ideally, adding another chemical dispensing machine is required in order to improve the CT below Takt Time. Upon considering 8 Waste concept in Motion Waste improvement, the machine movement and distance were analyzed for further improvements.

4. Result and Discussion

4.1 Assessment Contribution

Improvement obtained from the Lean Manufacturing Implementation has been summarized in the Table 4 shown below. The benefits obtained from the implementation are reduced bottleneck cycle time, increased line efficiency, reduced manufacturing cost and greater revenue for the company.

Table 4 - Cycle time comparison

Process	Previous Cycle Time	Proposed Improvement 1	Improved CT
MA 1	192.05	Semi-Automatic Jig to improve the operator handling time and improve the process CT	119s
TIM Machine	170	Reduce the gantry movement time and machine process time	126s
HLA 1A	150	Reduce the scanning processes and manual handling movements by Operators. Utilize automated curing to minimize manual pallet handling by Operators.	118s
HLA 2	164.45	Merge the process with MA3	99.4s
FVT 1	195.5	Split the process to use 2 operators. CT can be split into 2 that is 98s	101s
HLA 6	161	Split the process to use 2 operators. CT can be split into 2 that is 81s.	92s
HLA 8A	207	Split the process to use 2 operators CT can be split into 2 that is 104s.	110s
HLA 9	149	Improve the process and scanning process to reduce manual handling time	96s
FVT4	158.01	Involve more testers to cater in the requirement	125.3s
HLA 11	135.7	Improve the process and scanning process to reduce manual handling time	63.5s

4.2 Process Line Productivity Results

The targeted results have been achieved on the Takt Time of 126sec with PFD 15% to improve the output of Model X from 1500 units to 3000 units. Fig. 2 below shows the CT with 70% Line Balancing Rate and 70% Operator Utilization rate.

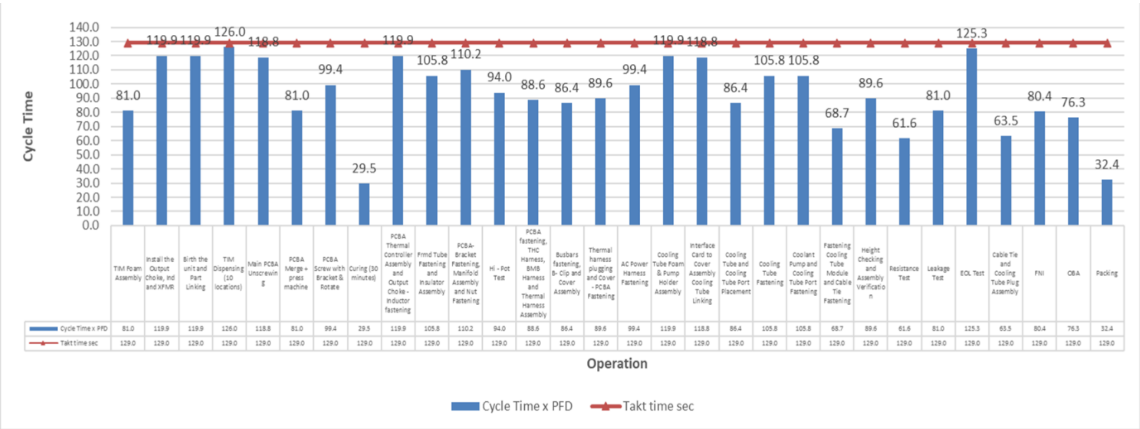

Fig. 2 - Cycle time chart after improvement

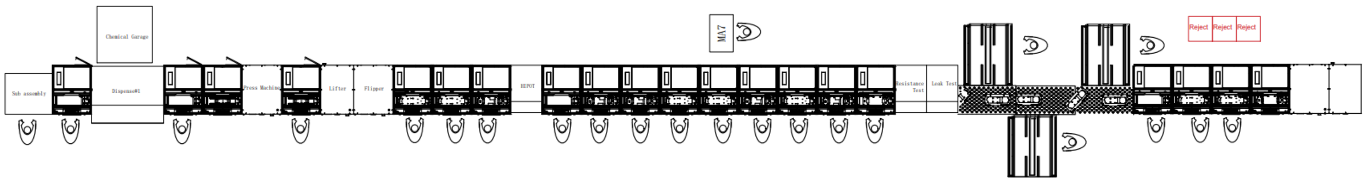

Fig. 3 - Old line configuration before improvement

Fig. 4 - New line configuration after improvement

Fig. 3 and Fig. 4 show the configuration be old line before improvement and new line after improvement. Additional space required is only 15.2 square meter. Based on the results obtained, it is conclusive that Implementation of Lean manufacturing can help to improve the Line Productivity. In the case study, the Line UPH has been improved from 14 units / hour to 34 units / hour by simply adding 4 workstations and 3 extra HC. This is tremendous improvement as the Line layout space and HC only increased by 12% but the Output of the line been increased by 120%, which means the revenue for the company also increased by 120%.

Table 5 - Table comparison

Criteria	Current Setup	Planned based on 3000 unit demand	Future Setup after Lean Improvement
HC Used	22HC	44 HC	25HC
Space Consumption	52.8 sq.m	105.6 sq. m	68 sq m
UPH	14	28	34
Weekly Output	1505	3010	3655
Profit / week	$82,775	$165,550	$201,025

Based on Table 5, Current Setup indicates the current line configuration of model X, Planned based on 3000-unit demand column shows the request from Company ABC management to setup 2nd line since the demand has doubled and Future Setup after Lean Improvement column shows the output is achievable through addition of 4 stations and 3 additional HC.

4.3 FlexSim Model to Evaluate the Results

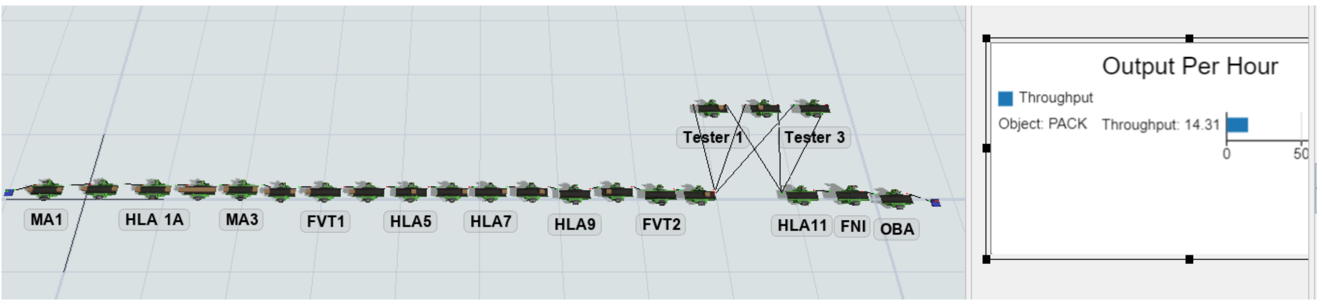

Fig. 5 - Existing model illustration

The production setup was configured in FlexSim software to simulate the Output per hour. The mode was built using simple setup and configurations.

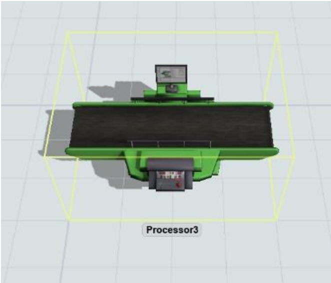

Fig. 6 - Workstation in FlexSim software

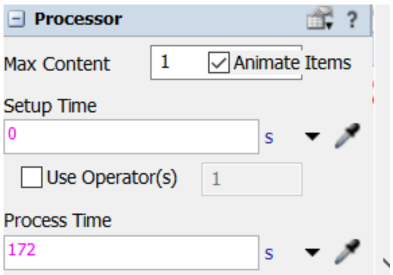

Fig. 7 - Process time configured as per individual station CT

Fig. 6 and Fig. 7 shows the simple mechanism used to configure the model of the production line in FlexSim. The actual process time in the current line was set onto the model and the Output per Hour was monitored and it has consistently maintained at 14 UPH. Based on improvements that have been planned using the concept of VSM and 8 Waste, the simulated Cycle Time was input to monitor the Output per H.

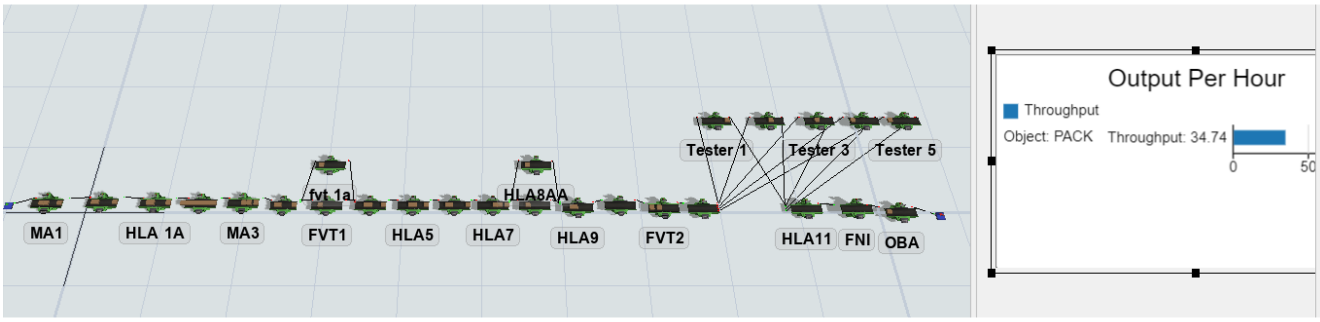

Fig. 8 - Improved line

Based on Fig.8, there were only 4 stations added to improve the line Output per Hour. The stations added are illustrated in Fig. 8 and the stations are

a. FVT 1
b. HLA 8AA
c. Tester 4
d. Tester 5

5. Conclusions

Lean manufacturing is a production process based on an ideology of maximizing productivity while simultaneously minimizing waste within a manufacturing operation. The lean principle sees waste is anything that doesn't add value that the customers are willing to pay for.

The 8 wastes of Lean concept or TIMWOODS is a powerful set of tools that can help organizations become more efficient and cost effective. These wastes include Transportation, Inventory, Motion, Waiting, Overproduction, Overprocessing, Defects, and Skills. By understanding the negative consequences that each waste can have on an organization's performance and bottom line, companies can use Lean TIMWOODS to make improvements and gain competitive advantages.

Value stream mapping (VSM) is defined as a lean tool that employs a flowchart documenting every step in the process. Many lean practitioners see VSM as a fundamental tool to identify waste, reduce process cycle times, and implement process improvement. VSM is a workplace efficiency tool designed to combine material processing steps with information flow, along with other important related data. VSM is an essential lean tool for an organization wanting to plan, implement, and improve while on its lean journey. VSM helps users create a solid implementation plan that will maximize their available resources and help ensure that materials and time are used efficiently.

Implementation 8 Waste and VSM into a Manufacturing Line will ensure elimination of waste which provides huge benefits in the Line Productivity Rate. A manufacturing companies' goal is to maximize productivity while minimizing resources. Company ABC has demonstrated improving its output from 14 UPH to 34 UPH from the implementation of 8 Waste and VSM.

In this study,the contributions of Lean to process line in the company has been identified by minimizing the operator movements, easing the operator load while working and eliminating all the Non-Value-Added activities. The process line productivity and maximize the efficiency of the production process has been done with improved Line Balancing Rate to 80% and the Output of the line can be doubled by adding only 4 stations and 3 HC in the production line. A model was developed using FlexSim software and demonstrated the efficiency improvement of the production line after application of Lean six sigma method.

Acknowledgement

The authors fully acknowledged Universiti Tun Hussein Onn Malaysia for supporting this work.

References

[1] M, S. (2018). Industry 4.0 and Lean Management : a proposed integration model and research propositions. Production & Manufacturing Research.
[2] Mrugalska B, W. M. (2017). Towards Lean Production in Industry 4.0. Procedia Engineering.
[3] Santos BP, C.-S. F. (2018). Interaction between Lean Philosophy and Industry 4.0 : Exploratory Study. IRF2018: 6th International COnference Integrity-Reliability-Failure.
[4] Mayr A, W. M. (2018). Lean 4.0 - A conceptual conjunction of lean management and Industry 4.0. Procedia CIRP 2018.
[5] Adeyemi, B. A. (2021). Combining simple motion measurment, lean analysis technique and historical data review for for countering negatice labor cost variance. International Journal of Engineering Business Management.
[6] Zhou, B. (2016). Lean Principles, practices and impacts : a study on small and medium sized enterprises (SMEs). Ann. Oper. Res 241.