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Effect of the surface mounting technology assembly based on lean production: A case study

Vo Tran Thi Bich Chau[1*] and Nguyen Nhut Tien[2]

[1]*Department of Industrial Management, College of Engineering Technology, Can Tho University*

[2]*Department of Electrical Engineering, College of Engineering Technology, Can Tho University*

**Correspondence: Vo Tran Thi Bich Chau (email: vttbchau@ctu.edu.vn)*

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ABSTRACT

Lean production is a popular technology which is applied widely and brings a lot of benefits. Many electronics companies in Vietnam apply this technique to eliminate wastes and enhance effectiveness. This paper is to present a study on the application of lean production on a Surface Mounting Technology (SMT) line. In this research, the SMT assembly line with a traditional batch production model would be transferred to lean production-oriented model. This work was begun by realizing the current state value stream mapping and then identifying wastes to establish an implemented plan. Reengineering of the SMT line focused on the aspects of reduction such as reducing wastes, standardizing works, and improving the layout. Some positive results were recorded such as increasing about 50% productivity per each shift, decreasing lead time from 6 days to 192.76 seconds; moreover, controlling the end-line quantities in a day was fixed. Furthermore, the application results are discussed especially.

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1 INTRODUCTION

Over the past several decades, many industrial zones have been established, and factory companies have been newly invested, leading to a trend of industrial development. The global modernization has been creating competition among enterprises more and more fiercely. There are a lot of problems in the field of technology, of which two issues that affect competitiveness are production cost and product quality. There are always issues at workplaces such as a large number of semi-finished products at workstations and production bottlenecks caused by the deficiency of synchronization. To improve the competitiveness of enterprises themselves in the context of global competition as severe today, they must constantly improve their production line. Lean manufacturing is not a new technology but has been studied and applied in many countries such as Japan, the Republic of Korea, USA, and many European countries. Lean was introduced by an engineer after the occurrence of World War II, and firstly designed for production lines of Toyota Company, or Toyota Production System (Ohno, 1982). Philosophy of this system is to eliminate wastes, empower human resources, reduce inventory, and importantly meet customer demands. Instead of storing required resources for future production, Toyota Company has built up a good relationship with suppliers. In addition, by training multi-skill workers, the company could arrange them in flexible ways; therefore, it could meet the unstable customers' demands better than competitors could. Lean methodologies are a compilation of many techniques, which was used by many companies in the past. The difference is the consolidation of these techniques into one set of powerful methodologies and their applications. Specifically, they are a series of techniques that allow producing one unit at a time, and at a formulated rate while eliminating none of adding-value waiting and queuing time or other delays. Lean technology is a systematic approach method to maximize customer requirements at the highest level as well as minimize wastes.

In Vietnam, numerous studies have consistently found that value stream mapping (VSM) leads to improvement in aspect of lean production system. The implementing VSM process are to find out the main causes of waste such as the difference between the output, the daily target, work in process (WIP) at many stages and the unreasonable layout. In the future, researchers will come up with several methods to eliminate wastes and improve efficiency and effectiveness. A recent study clearly showed various benefits of VSM, providing opportunities for Clipsal Vietnam Co with improving productivity (Phong *et al*., 2015). East West Industries (EWI), which belongs to East West Manufacturing group, established construction for its first Vietnam facility in April 2008 with the main types of production, being called an assembly, injection molding, metal stamping, pad printing, warehousing, and offices. This paper is to improve the competitiveness of the company. With a strong focus on quality, engineering, and satisfying our customers, EWI is poised to continue to deliver competitive manufacturing or domestic and international customers. To put it another way, this study will provide the steps of lean implementation in detail, and proposes the STM processing improvement line to reduce the wastes.

2 LITERATURE REVIEW

Lean technology is a systematic approach method to maximize meeting the demand of customer at the highest level as well as minimize wastes. VSM is one of the tools that is a key tool to identify the cause of waste in the process and steps can be taken to reduce or eliminate it. This philosophy was first introduced by the researchers who argued that eliminating waste was the biggest goal the system wanted to enhance (Womack *et al*., 1990). VSM is developed to overview the value processing of lean manufacturing systems. Other report introduced an overview of the VSM; the steps involved in making it and analyzed the causes of waste in all processing (Wade and Hulland, 2004). A case study of the "Lean" approach was presented, using the main tool of the value stream to draw a simulation model of the production line at a steel company (Abdulmalek and Rajgopal, 2007). This study gives the potential benefits of this tool, reducing producing time and inventory time. Especially, a case study in India had applied a VSM to enhance the streamlined operations to minimize cycle time in the production process (Seth *et al*., 2008). The report showed that VSM has proven effectiveness in identifying and eliminating wastes according to the basis producing processes, namely assembly facilities. VSM is used as an advanced tool to improve the supplier's productivity in the automation industry. The researchers presented the current data collection and the current VSM that analysing the actual wastes, proposed the specific changes to the lean production model (Yu *et al*., 2009). In addition, a systematic approach based on the technical value of the VSM was developed to identify the current processes. Besides, layout design is a very important issue in production, management, and control. Balanced peanut included the assignment of tasks required to handle a product, to the allocation of machinery so that idle time is minimized (Dolgui and Gafarov, 2017). Balanced line should be done in most production lines, but bottleneck nodes often occur. There were many simple balancing methods that bring efficiency and quality of the production line to be shown in productivity and balance indexes (Lam *et al*., 2016). In addition, cellular layout is performed after the problem has been solved. In the cellular layout system, the machines have grouped into multiple cells, each dedicated to a specific family, and the goal is to maximize the independence of cellular manufacturing system (Pattanaik and Sharma, 2009). Kleiner (2006) argued that engaging in larger system components such as organizational design and management was not a novel for chemists; however, it was built by providing the specific methods and tools result in large-scale results. To improve production efficiency, other authors looked at the causes of job stress reduction as stress and management; moreover, technical solutions could be used to improve human performance (Murray and Thimgan, 2016). Special considerations have given to minimize the risks associated with human fatigue, error checking and reliability analysis. In the context of increased computerization and automation, which have caused changes in human work in production, the report showed that human factors and interactions between humans with the machine affect the design of production systems (Becker and Stern, 2016). In this article, the research provided a list of human tasks in the present and future cyber-physical production system (CPPS), including a trend estimate for the decline, increase, or change of these additional tasks. Finally, the authors combined the findings with expert assessments of CPPS trends and recent employment data from the German job market. In addition, a report has also reviewed the theories and motor control factors that affect the performance of motion and indicated that internal movement changes are part of the complete mission (Gaudez *et al*., 2016). To clarify this platform, industrial engineers need to better understand the influencing factors and then use methods to improve the design tools. In this way, the simulations created by the designers for the workstation design should be closer to the motions made by the workers. Quality improvement methods show great potential in the production process as they use an empirical approach to reduce change and improve work processes (Amaratunga and Dobranowski, 2016). The analysis was originally done using causal diagrams, Pareto charts, study of setup time and performance indexes to find out the main problems, using the tools in lean to improve the quality of production processes such as single-minute exchange of dies (SMED) and 5S. In practice, the application of innovative tools depends on a variety of conditions such as environment, production industry, available resources, etc. Although quality improvement approaches are of many benefits, it is also necessary to conduct research on the risk of the misleading system to better understand and timely issue, timely solutions (Mason *et al*., 2015).

3 METHODOLOGY

The steps are shown in Figure 1 and based on the problems in this company provide more detail on this method.

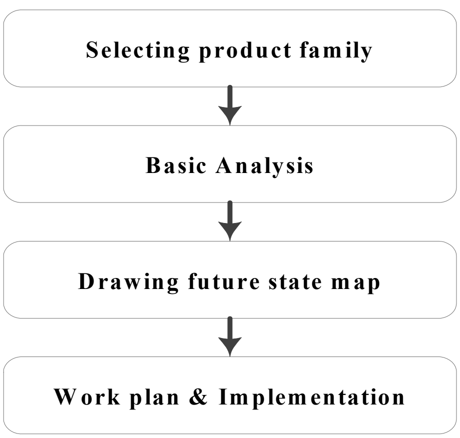


Fig. 1: Methodology of implementation research

3.1 Selecting product family

Applying top-down analysis method, this study has analysed the components, factors related to all operations in this system. To systematic top-down analysis, they need to perform the following tasks such as 1) what are the common goals in the system; 2) collecting and revising all information of each department. This makes discussion and decision easier.

3.2 Basic analysis

Focusing on the information collected, this research paper is to build a logical model that demonstrates relationships between components in the system. From the logical model, using the tools of VSM simulates the operation of parts related to the company's production. Next, simulation results are used to identify the cause and problem of the current system. Based on relevant theory to a system improvement plan developed, the results of the improvement options have been reassessed according to the improved simulation model.

3.3 Drawing future state map

The future state VSM has established based on improved suggestions. In order to minimize inventory wastes, lean tools are used to improve and achieve the capacity of the processes. In the demand stage of this paper, re-designed layout and balanced assembly workstation are applied commonly. The improved actions for the design of a future-status map set up a continuous flow which experiences a process with smoother, without returns, producing in the shortest lead time, highest quality, and lowest production cost.

3.4 Work plan and implementation

The improved suggestions based on the problems have been established, and shown in the next section. The tools employed in this paper make it possible for the organization to get continuous proposal in terms of key stakeholder. All non-value-added activities are systematically and continuously excreted to decrease the costs and rise turnover thanks to lean manufacturing initiatives. Lean plays a vital role in the market for manufacturing industries to survive and succeed. Lean manufacturing includes easy-to-apply and maintainable techniques, and tools that enable organizations to attain planned productivity. Reducing and eliminating wastes gradually become the culture of the organization which might turn every process into revenue.

4 CASE STUDY

4.1 Product family

Currently, the production line of the company always has a large amount of semi-finished products in the field of electronic board production. The layout of the workplace causes many difficulties for workers with the presence of WIP, especially in the assembly and finished products. Many products have been stored for a long time for packaging and exporting. Therefore, the production of the plant has not been very effective. This article focuses on SMT processing in Figure 2 and has chosen the main product which accounts for 70% of the total products in the company.

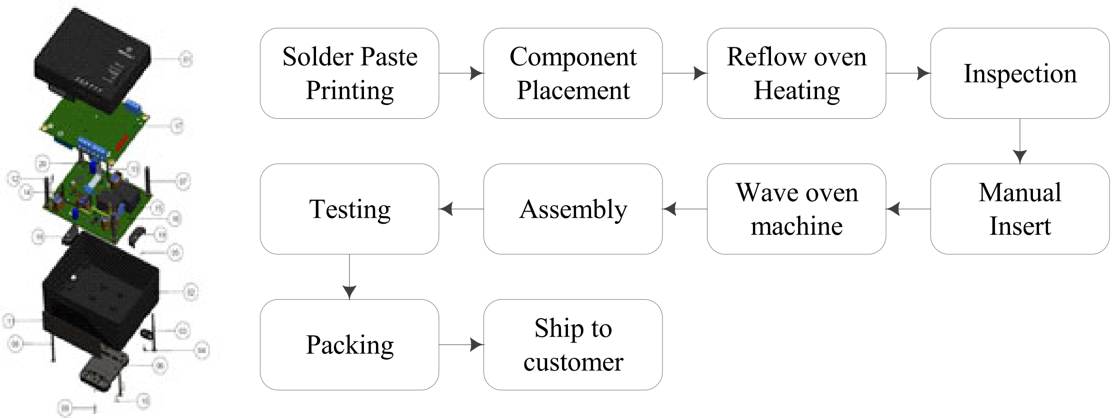


Fig. 2: Processing of the main product SMT line

Surface Mount Technology is an area of electronic assembly used to mount electronic components to the surface of the printed circuit board (PCB) as opposed to inserting components through holes as with conventional assembly. The first machine setup in the manufacturing process is the solder paste printer which is designed to apply solder paste by using a stencil and squeegees to the appropriate pads on the solder paste printing PCB. After pasting, the boards are carried to the pick-and-place machines placing them on a conveyor belt. Each component is picked from its packaging using either a vacuum or gripper nozzle, checked by the vision system and placed in the programed location at high speed. Following the component placement process, it is important to ensure no fault occurrence; moreover, all parts have been correctly placed before reflow soldering. One of challenges for sub-contract manufacturers is the verification of the first assembly to the customer's information or first article inspection which is time-consuming. This is a very important step in the process as any undetected errors, that can lead to high volumes of rework. Once all component placements have been checked, the PCB assembly is moved into the reflow soldering machine where all the electrical solder connections are formed between the components and PCB by heating the assembly to a sufficient temperature. It appears to be less complicated part of the assembly processes; however, the correct reflow profile is key to ensure acceptable solder joints without damaging the parts or assembly due to excessive heat. A carefully-profiled assembly plays a vital role in using lead-free solder since the required reflow temperature need components which may reach maximum rated temperature. Finally, the boards are visually inspected for missing or misaligned components and solder bridging. In case of failure, they are sent to a rework station for repairing. Moisture-sensitive goods in dry bags are also marked with a special label including corresponding warning information

The plastic box is unfocused in this study because it is processed from an external supplier. Customer demand had increased from 10,000 pieces per month in three months (from June to August), but in September the demand increased to 30,000 products per month. Therefore, there are some main points to be taken as 1) the current capacity of the process is not enough to meet customer requirements; 2) the rate of semi-finished products between workstations is high; 3) wastes occurred on the line; 4) resources are inadequate. Working time in the company is 7.58 hours/shift/ day. Data is calculated based on the customer demand. Takt time is 23.7s, the output is relatively hard to produce for 30,000 pieces/month.

– For 10,000 pieces/month:

$$Takt\ Time = Time\ available / Demand\ customer = \frac{7.58x26x3600}{10000} = 70.92\ (s) \quad (1)$$

– For 30,000 pieces/month:

$$Takt\ Time = Time\ available / Demand\ customer = \frac{7.58x26x3600}{30000} = 23.7\ (s)$$

Machine workstations are automatically driven by a specified speed, so this study focused on balancing with the manual workstations, which is plug components workstation. Steps for circuit board parts are passed to component 3 in Figure 2 while work element shown in Table 1 is calculated according to below formula (Niebel and Freivalds, 2003).

Using the sample mean and sample standard deviation: $s = \sqrt{\frac{\sum_{i=1}^{i=n}(x_i-\bar{x})^2}{n-1}}$ (2)

Solving for n yields: $n = \left(\frac{ts}{k\bar{x}}\right)^2$ (3)

Table 1: Observed time in circuit board assembly line

Step	Printed circuit ID	Work Element	s	n	Average Observed time (s)
1	10	Loading pallet & Put Board	1.0	13	13.9
2	20	Insert Capacitor C2	0.7	44	5.3
3	30	Insert Capacitor Thermal Fuse F2&F3	1.3	25	13
4	40	Insert Varistor M1A & M1B	1.5	32	8.4
5	50	Insert Capacitor Thermal Fuse F4&F5	0.2	10	13.8
6	60	Insert M2a, M2b, M2c, M2d,	0.7	91	16.6
7	70	Insert Wire P1	1.4	68	5.5
8	80	Insert Wire P2	1.2	14	4.7
9	90	Insert Relay K1	1.2	14	3.5
10	100	Insert Relay K2	0.8	54	3.9
11	110	Insert P2	0.5	31	4.7
12	120	Insert NCT N1	0.5	26	5.7
13	130	Insert Wire P3	0.5	31	4.7
14	140	Insert M3a, M3b, M4a, M4b2	0.5	31	16.6
15	150	Insert Wire P4	0.5	31	4.7
16	160	Checking component	0.5	31	17.3
17	170	Insert Wire P5	1.4	17	4.7
18	180	Loading pallet & put to machine	1.2	3	36.2
Total					183.2

Before improving (7.58 working hours per day), Standard Time is set up in Table 2 and calculated according to below expression (Niebel and Freivalds, 2003).

– The normal time (NT): NT = OT x R/100 (4)

– The expression for standard time (Becker and Stern): ST = NTx(1+Allowance) (5)

Table 2: SMT line capacity planning

Task No	FC ld.	Station	Basic Cycle			Std. Time (s)	Operator
			Observed time (s)	Rating (%)	Variable Fatigue		
1	10, 20, 30, 40	Manual Insert 1	45.97	90	15	47.58	1
2	50, 60, 70, 80	Manual Insert 2	32.27	90	5	30.49	1
3	90, 100, 110	Manual Insert 3	26.97	90	5	25.48	1
4	120, 130, 140	Manual Insert 4	24.37	90	5	23.03	1
5	150, 160	Manual Insert 5	9.43	90	5	8.91	1
6	170, 180	Manual Insert 6	53.47	90	5	50.53	1
Total						186.02	6

There is no balancing between workstations. Figure 3 shows that the Takt time is 70.92 seconds, but most of the time workers have high idle time; however, the number of required workers are six workers.

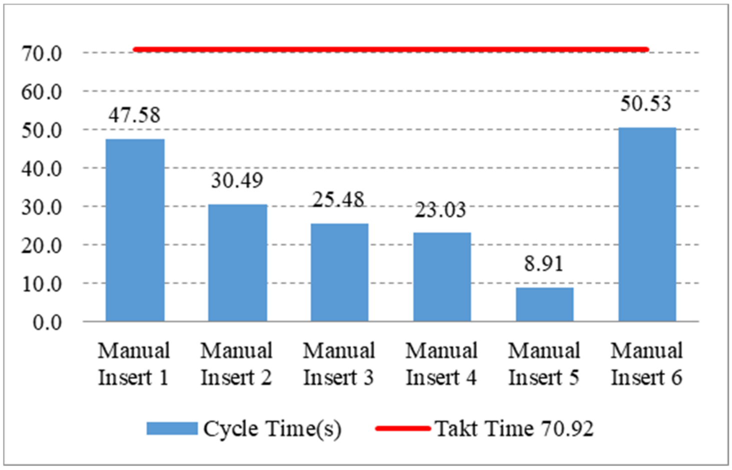
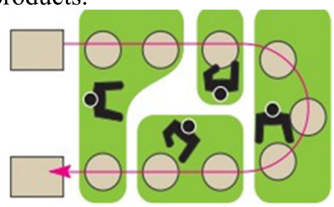


Fig. 3: Cycle time of component 3 processes

4.2 Basic analysis

The current layout in this company is designed in U-shape; therefore, this type of line makes it easy to utilize the most available resources, to balance, to be suitable for lower output, and to change products. Besides, it is difficult to respond to the increasing production because semi-finished products in each stage will increase. After products are finished, they need to be moved to the warehouse area as illustrated in Figure 4



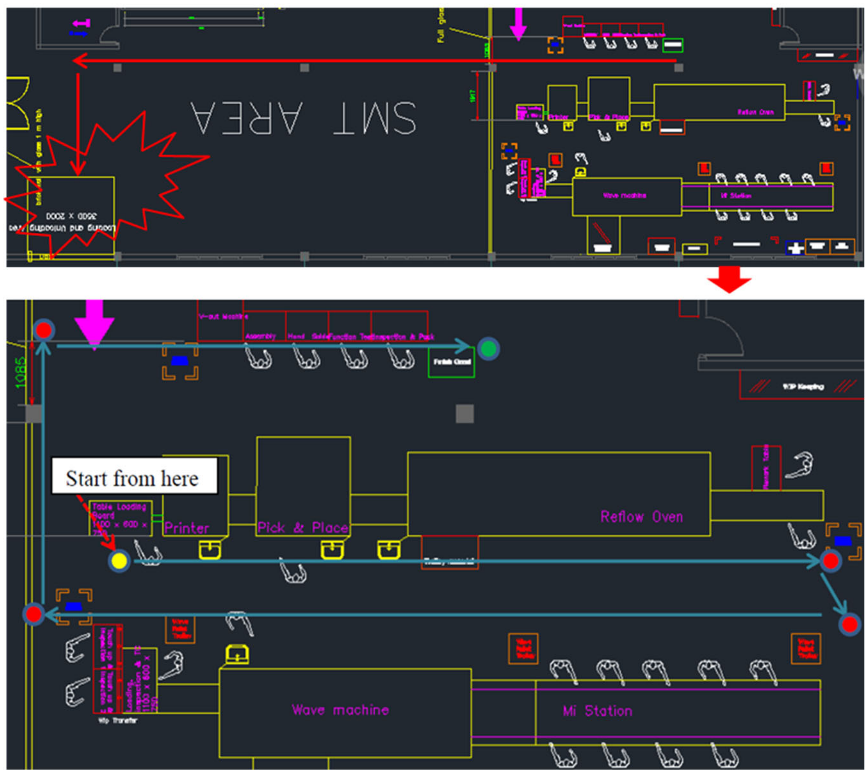


Fig. 4: The current layout of warehouse area and SMT line

The diagram shows some disadvantages which the VSM tool might identify. Moreover, the measured parameters of all stages in this processing in Figure 5 clearly show the disadvantages.

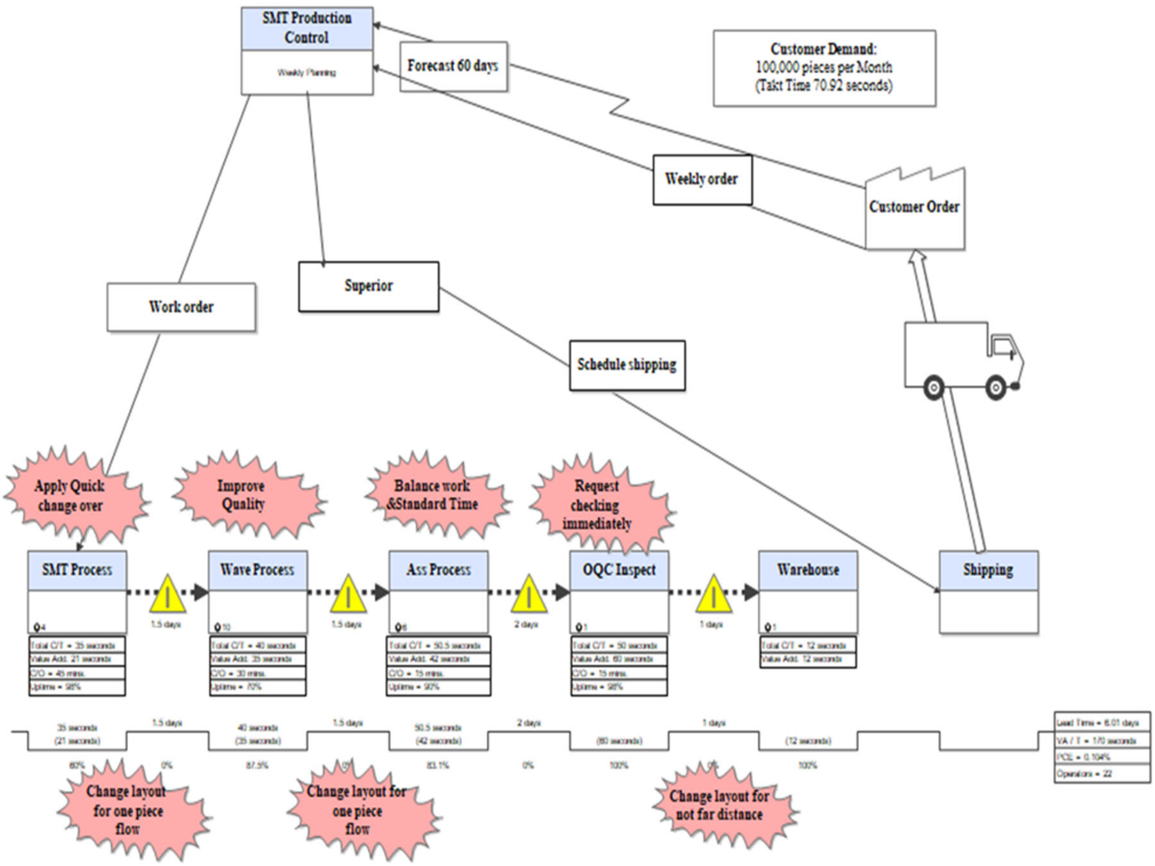


Fig. 5: The current state VSM of SMT line

As shown in Figure 5, it is possible to indicate the types of waste as follow 1) The Waste of Motion: the distance of each station is far, following the Batch to Batch; 2) The Waste of Waiting is unbalanced between the workstations, having many workers to wait for other operations for a long time.

4.3 The future VSM

The company decided to make two shifts each day to meet the customer demand. Working time is as follows: 1) 1st shift (from 6 AM to 2 PM): 30 minutes for breaking time (from 10 AM to 10.30 AM) and 5 minutes of implementing 5S last hour; 2) 2nd shift (from 2 PM to 10 PM): 30 minutes of breaking time (from 6 PM to 6.30 PM) and 5 minutes implementing 5S. Finally, each shift has about 7.42 working hours and 14.84-hr day/2 shifts and meets the demand in 30,000 pieces/month.

$$Takt\ time = Time\ available / Demand\ customer$$

$$= \frac{15x26x3600}{30000} = 46.3\ (s)$$

As shown in Figure 6, productivity increased from 10,000 pieces/month to 30,000 pieces/month (about 50% per a shift), and lead time was reduced from 6 days to 192.76 seconds based on the mentioned solutions in the current VSM. Besides, some solutions have not been performed in this case study such total quality management, total productive maintenance, and SMED that are called long-term solution to improve the working environment.

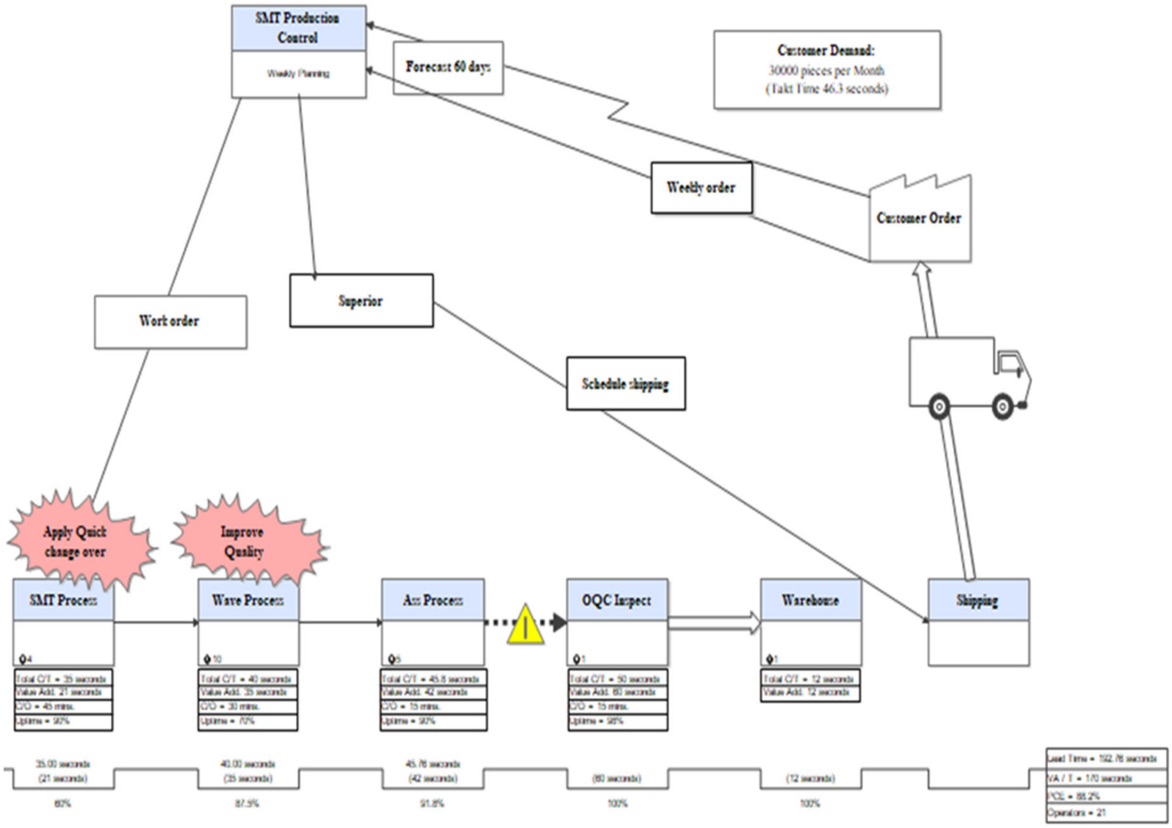


Fig. 6: The future VSM

4.4 Implementation and results

4.4.1 Redesigning layout

There are two main approaches to site relocation problems: building algorithms and improved algorithms. An improved algorithm is used to solve the problem of relocation of premises for this study. Moreover, the cell layout after solving the surface problem has been completed, based on visual perceptions and visual production, which are used to improve and evaluate. The layout is designed as shown in Figure 7 to allow the production flow easily, reducing the rate of semi-finished products at each stage, and decreasing the waste of motion between areas.

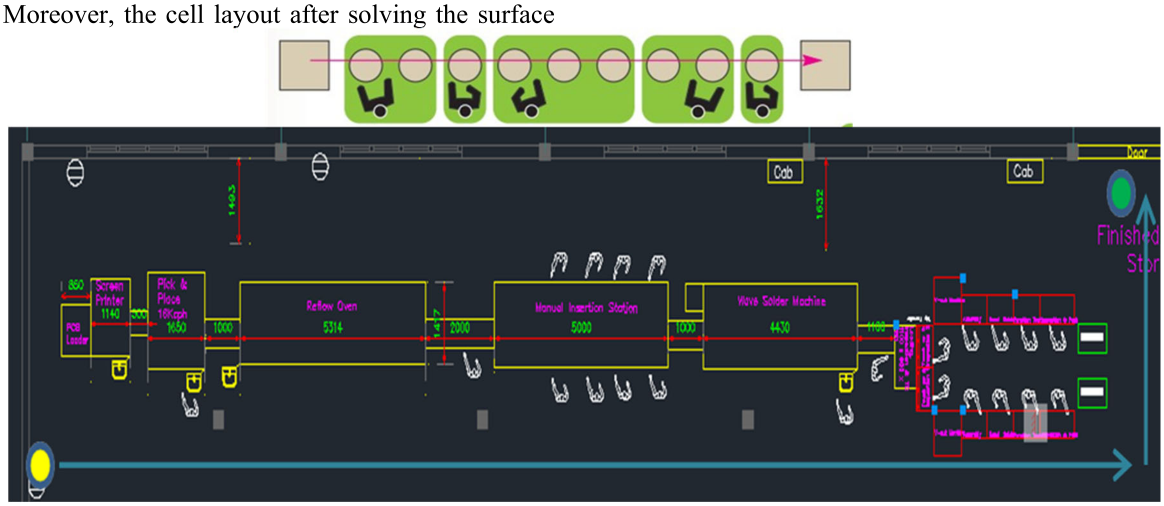


Fig. 7: The redesigned layout in SMT line

4.4.2 Balancing line

It is essential to reduce and improve cycle time to meet better customer demand. Based on data of workers' operations, operations are be arranged more consistently and matched requirement. After planning the new scheduling for 14.8 working hours/ day in assembly workstation, namely setting up the standard time, rating of the performance of Westinghouse system and allowance present in Table 3 (Niebel and Freivalds, 2003).

Table 3: Standard time of assembly WS

Task	FC ld.	Basic Cycle Observed time (s)	Rating (%)	Allowance (%) Constant	Allowance (%) Variable Fatigue	Std. Time (s)	Operator
1	10, 20, 30, 40	40.55	95	9	6	44.30	1
2	50, 60, 70, 80	40.57	95	9	6	44.32	1
3	90, 100, 110, 120, 130, 140	39.02	95	9	6	42.63	1
4	150, 160, 170	26.73	98	9	6	30.12	1
5	180	36.17	110	9	6	45.76	1
Total						207.13	5

In Figure 8, the next proposal might improve cycle time to meet customer demand, especially attending in Manual Insert 4. Basically, rearranging the operations might suit the requirements and the productivity before and after improvements are shown line efficiency is increased from 44% to 89.5%.

$$Line\ efficiency\ (Before) = \frac{Total\ cycle\ time}{Total\ work\ station\ x\ Takt\ Time} = \frac{186.02}{6\ x\ 70.92} = 44\%$$

$$Line\ efficiency\ (After) = \frac{Total\ cycle\ time}{Total\ work\ station\ x\ Takt\ Time} = \frac{207.13}{5\ x\ 46.3} = 89.5\%$$

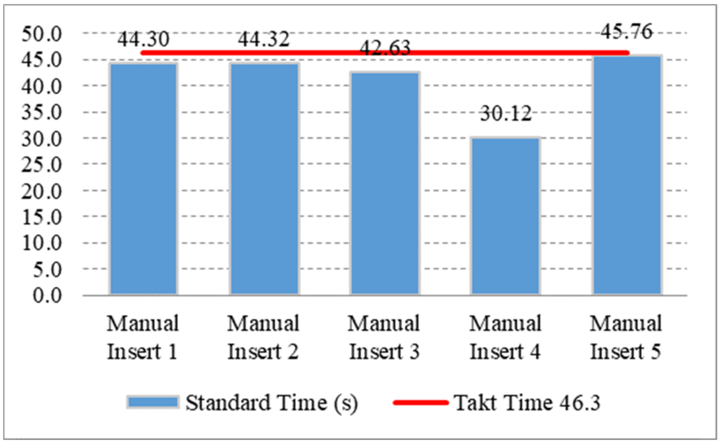


Fig. 8: Compensation of cycle times and Takt time after improving

4.4.3 Improving work environment

Standardized work practices detail how work should be identified the steps and problem operations. Thereafter, the standard is improved according to the given criteria in Figure 9 (Pheasant, 2014)

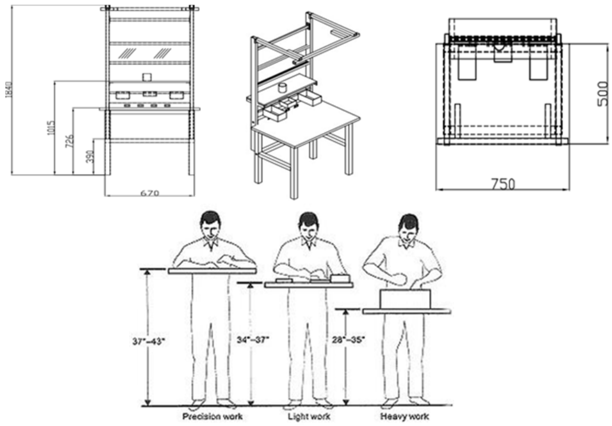


Fig. 9: Designed workstations

All necessary items are arranged in front of the workers, enabling them to work easily. In addition, the lighting system satisfies electronic industry standards, supporting to increase productivity, work efficiency, reducing defects and improve quality. In many cases, workers stand for hours at a hard surface causing fatigue and distraction at work. Fatigue-resistant carpets are offered to solve this problem in Figure 10 (Quinn and Billings, 1989).

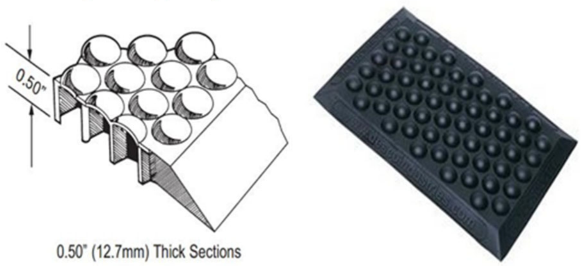


Fig. 10: A sample of fatigue-resistant carpets

Carpets might relieve the impact on the soles of the feet. However, this solution just reduces fatigue of workers while standing for long periods.

4.4.4 Implementing 5S principles

5S application might make the workshop more organized and scientific and save time for research tools. Maintaining a good habit and a clean environment is to improve productivity and quality of work in Figure 11.

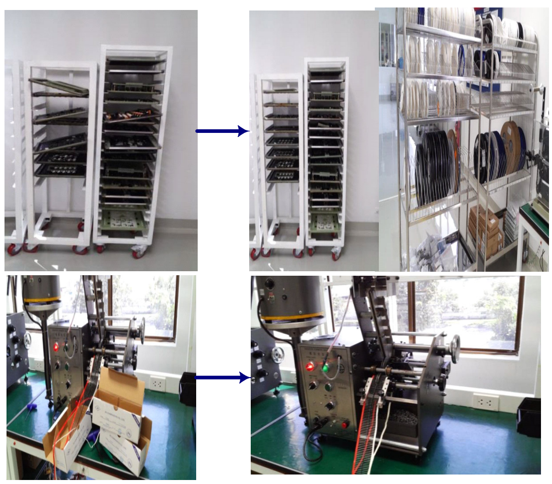


Fig. 11: An implementation of 5S tool

– In addition, it is important to establish standard operation procedure for maintenance guidance and standard time.

– Perform and document preventative maintenance and repair operations follow as required

– Maintenance method follows guided line in the manual book for each model (hard copy or soft copy which latest version).

– Machines have maintenance schedule daily, monthly such as Wave machine, Printer Machine, Reflow machine, Pick and Place machine. Machine maintenance daily performed by SMT technician or Machine Operator and monthly performed by SMT Group (Technician, Engineer). The record is to create a standard operation and follow the instruction after Printer Machine was performed in Figure 12.

Tools/Equipment		
Printer Machine		
IPA spray		
Electrostatic Gloves & Wrist Weld Strap		
Materials		
Code	Description	Q.ty
OM-338	Lead-Free SAC305	1
V111810601	Smartlie PCB Board	25
Operation Time		
Assembly	40 seconds	25
Testing	40 seconds	10
Quality Requirement		
Visual		
1	Check the lead on the right side of the board.	
2	Check for lead short circuit or not.	

WORK INSTRUCTION		
Process Name	Put Board Into Printers, Prints & Leads on Board	P-WI-1118-01-A
Operation Description		
Step 1	Check if the lead is on the stencil or not, if the stencil is working. Correct with the model selected then put the board into the rail of the lead zinc machine, note that the board direction is set correctly, and the board placed on the outside of the machine is not inserted in the machine to avoid being pulled.	
Step 2	After putting the board into the machine, the machine automatically prints zinc on the board, then checks whether the board quality is satisfied or not.	

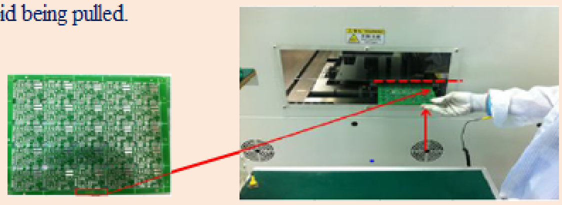


Fig. 12: Standard operation procedure of printer machine

5 RESULTS AND CONCLUSIONS

This paper has met the objectives with the advantages of following strict and scientific methodology, using many tools, achieving the following results after performing lean system such as 1) increasing productivity from 10,000 pieces/month to 30,000 pieces/month (about 50% a shift); 2) reducing lead time from 6 days to 192.76 seconds; 3) improving the proportion of finished products on the line from 44% to 89.5% in Table 4.

Table 4: Comparing the effectiveness of VSM before and after improvement

Content	Before	The future VSM
Lead time	6 days	192.76 s
Operators	22	21
Takt time (second)	70.92	46.3
Line efficiency (%)	44	89.5

Although this implementation has not explicitly shown the saving costs, it helped all staff know about the real meaning of lean system and the activities will be value-added or bring the value back to them. The results of the study are the basis for further research on the application of lean production tools to the production line and the extension of research to other lines in the company as well as other electronics companies.

In general, this research still faces some barriers from workers, being touched by individuals all fresh time. It needs to take a period to change their thinking way individually. Therefore, in order to successfully apply lean model and to maintain efficiency, it is necessary to establish a lean team with a training plan, specific training content, and details clearly for the next research. However, most companies do not realize the majority of production costs in non-value activities. This leads to a bias in the calculation and selection of improved solutions. Therefore, managers need to focus on losses and minimize or eliminate waste by redesigning the future plans which might meet precisely the condition of their company. This will help the company increase its competitiveness in many aspects such as prestige, price, productivity, and quality.

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