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Improvıng Inventory Tıme in Productıon Lıne through Value Stream Mappıng: A Case Study

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Abstract

Value Stream Mapping (VSM), an illustrated method that describes the flow of raw materials and the values that customers provide, shows the main stages of the operation process, besides data related to the material flow, quality, order fulfillment time, and production rhythm. This research focuses on building VSM for the computer desk production process at School Equipment Workshop, College of Engineering Technology, Can Tho University. In this study, the order date has been collected to select the product family to streamline the production process, working time, processing time for each stage, inventory quantity, and time of inventory usage. The current VSM determines wastes and bottlenecks in the production process. Using Lean tools (i.e., 5S, balancing line, traction production, inventory shelf, Kanban, and FIFO cards) will be employed for continuous improvement and establishing future VSM based on these suggested improvements. Finally, the Arena model simulates the production process before and after improvements, considers workers' performance, and identifies bottlenecks. The study will clearly show optimal results after using lean tools and simulating the computer desk production process of the factory. The findings showed that production time declined by 12.6 hours (improved by nearly 25%), while the Process Cycle Efficiency increased by 1.36% (approximately 35% improvement). Finished goods and WIP time, which account for approximately 50% of inventory time, have dramatically dropped by 41%.

Keywords: Kanban systems, inventory time, Lean tools, simulation model, Value Stream Mapping

1. Introduction

Nowadays, Lean Manufacturing (LM) is a technology that has been studied and applied for a long time in many countries, such as Japan, the Republic of Korea, the USA, and many European countries. This system's philosophy is to eliminate waste, empower human resources, reduce inventory, and meet customer demands. Instead of storing required resources for future production, Toyota Company builds good relationships with suppliers. In addition, by training multi-skill workers, the company could arrange them flexibly to meet customers varying demands better than competitors. Lean methodologies are a compilation of many techniques' companies have used in the past and are familiar with. The difference is consolidating these techniques into one set of powerful methodologies and their applications. Specifically, they are a series of techniques that allow products to be produced one unit at a time, at a formulated rate, while eliminating non-value-adding wait time, queue time, or other delays [1, 2]. Almost all enterprises aim to increase product quality and minimize waste in businesses. LM, a concept based on the Toyota Production System (TPS), is a technique that many large enterprises worldwide have applied to maintain competitiveness in the globalized integration environment [3]. LM is to aims to eliminate waste and non-value-added activities. LM includes implementation management methods such as Just-in-time (JIT), quality systems, teamwork, manufacturing cells, and supply chain management in an integrated approach [4].

An extreme option is proposed to solve the lean production problems or, more specifically, is Value Stream Mapping (VSM). Lean tools can help the company reduce costs, deliver on schedule, and shorten the lead time. VSM is one of the LM tools and has been applied in many industries. VSM is created using a set of predefined symbols. It creates a common language about the production process, allowing managers to make valuable decisions to improve the chain value [5]. VSM is one of the visualization tools that help managers understand the data and information flow created through the value chain. It means mapping the value chain to follow the product's production path from the customer to the supplier and accurately visualizing every material and information chain process. Then, identify critical questions and plot future states. The researcher identified methods, such as 1) identifying related product families and goals for improvement; 2) building existing value chains for the product's value chains, using information gathered from the actual production process; and 3) mapping the future value chain. Companies that have long relied on traditional production methods, transforming the production process and adopting other innovative practices are problematic. That makes managers' commitment to Lean ineffective; they do not believe in lean production's benefits. This is a reason for applying simulation to the post-improvement manufacturing process. Simulation has proven to be a valuable tool to help quantify the effectiveness of LM adoption. In the study of

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Delty and Yingling, simulation has demonstrated the impact of lean principles on improving inventory, warehouse space, bottleneck, human resources, and equipment [6].

In Vietnam, many scientists have applied the combination of VSM and simulation to research to improve production lines and achieved many remarkable achievements. The future VSM was proposed to determine the production process's effectiveness. Ocean Shine Company, specializing in shrimp products manufacturing in Soc Trang City, Soc Trang Province, Vietnam, has applied the VSM method to streamline production [7]. East-West Industries applied many lean tools such as VSM, redesigning the layout, balancing lines, improving the work environment, and implementing 5S principles. Results increased productivity by about 50% a shift, reduced lead time, and enhanced PCE from 44 to 89.5% [8]. Tay Do Garment Joint-Stock Company determined the causes of waste in the production line via the VSM tool. The results showed that lead time decreased from 30.3 hours to 8.78 hours, WIP inventory decreased from 2844 to 818 pieces, and PCE ratio of initial 0.32% increased to 1.05% [9].

It can be said that VSM will be clearly illustrated in production and reducing waste. This paper aims to reduce production time, improve productivity, reduce waste, and increase customer-time delivery rates. The rest of the article is categorized as follows. The proposed VSM tools and indicates the literature review is illustrated in Section 2. Section 3 presents the proposed methodology for improving the production line. A case study and analyses of numerical results are discussed in Section 4. The results of an actual case study of the computer desk production process of the factory in Section 5 follow this. Finally, concluding statements on future works are given in Section 6.

2. Literature review

This section aims to present an extensive review of recent research applying Lean tools in the manufacturing industry to improve production time, eliminate waste and unnecessary motions, increase productivity, and enhance competitive edge.

2.1. Lean Manufacturing is an ongoing effort

Lean from the Toyota system is being applied worldwide to eliminate waste and inefficiencies in production, lower costs, and increase competitiveness for suppliers [1]. A group of authors introduces LM with the implication that waste disposal is the most considerable goal this system aims to achieve in the future. By definition, LM is an ongoing effort to eliminate industry waste and enhance products' added value. This method is a systematic approach to identifying and eliminating waste through continuous improvement and optimizing performance and production processes, as it can find, measure, analyze and find innovative solutions [10].

Moreover, businesses may produce more goods and valuable products, create good credits in the market, and price stability for the market [11]. Specifically, lean tools have been utilized to study time, single-piece flow, assembly lines, and the allocation of labour to redesign the layout and provide smooth flow on the maximal line in garment industries [12]. When the line changes to a new item, productivity is significantly lower. This article analyses the cause of the WIP fluctuation to find the main factors affecting the increase in line productivity when re-establishing the order and applying lean to machine preparation, training, layout, and line balancing before the commencement of production. These methods and techniques will significantly assist in rebalancing [13]. Using lean will reduce or eliminate downtime in production and achieve efficiency, productivity, and quality with a reduction in time consumption, labour force, machine, raw materials, and cost. Some tools and techniques applied in the production line are VSM, 5S, U line layout, skilled workers, using Kanban, pulling system, and so on that are needed to master [14].

2.2. VSM as a tool for lean enhancement

The performance of LM begins with the development of VSM [15]. VSM, one of leading lean tools, identifies opportunities for different techniques. This approach describes a simulation model formed to compare scenarios before and after a detailed description to present potential benefits such as reduced lead time and inventory in the production process [4]. VSM-based methodology and other tools were applied in the aircraft maintenance process to reduce maintenance service time and, subsequently, maintenance service fees [16, 17]. VSM's reality as a redesigned tool established; resources required for the application process are shown, and the difference between the theoretical conceptions proposed by VSM and their practical applications. These results have drawn conclusions related to communication solutions for researchers to achieve the highest significance when utilizing VSM and define theoretical development points for the VSM to evolve a reference in redesigning methods [18].

Through VSM, solutions are proposed to identify wastes to eliminate the identified waste. The current and future VSM are simulated and analyzed for various properties such as processing and takt time. The overall assessment is achieved using flow mapping values. The takt time prediction results decreased from 46 to 26.6 minutes and increased the value-added time by 74.5%. The simulation results show that the framework can apply to many small-scale industries. VSM aims to analyze the current situation and design the process for products/services through customer needs [19]. Systematic questioning techniques have been used to collect relevant data from charting the value of the production line, creating a current VSM that reflects the current state of operations. A future VSM was proposed as a direction for future lean operations. This case study suggested two Kaizen events [20]. The first Kaizen event used the experimental design to find optimal machining parameters reducing variability during plasma cutting. Thus, it eliminates rework time and improves productivity. The rabbit chase's second Kaizen event increased system flexibility and reduced inventory levels between workstations. VSM can help reduce costs in work and streamline work steps efficiently. VSM is a convenient visualization tool for Enterprise Resource Planning (ERP) optimization, as it can give the best overview and complete the entire workflow. A comprehensive methodology for sustainable VSM development has been presented by identifying appropriate indicators and methods to display them visually. The approach is validated by applying it to an industry case study, and opportunities for further improvement are discussed [21]. The current and future state of the supplier site scenario using VSM has been discussed to improve end-to-end supplier productivity for the automotive industry. That is analyzed along with takt time calculation and the application of other distance areas. Results showed that production affects productivity, such as output per worker, reduction of WIP, and finished product time [22].

It is said that VSM was used to simultaneously consider environmental and manufacturing wastes during the implementation phase of tasks. VSM considers the development of maps to assist project managers in diagnosing the current production state to suggest improvements in the future VSM [23]. VSM is one of the fundamental LM tools utilized to determine opportunities for different lean approaches. Before and after LM initiatives recognize potential benefits for managers, such as reducing lead times and WIP inventory [24]. Looking at overall efficiency systematically, VSM helps enterprises eliminate waste at the root, better rearrange the comprehensive, and increase competitiveness [25].

2.3. Application of VSM with the combination of some lean tools

VSM can help optimize resources, reduce costs, enhance quality, and decrease the environmental effects of construction projects. De Steur et al. researched applying a modified VSM process to analyze the challenges, situations, and opportunities for improvement in an ETO firm's business processes. It benefits identifying the direct waste sources that negatively affect performance time in ETO movements and improving lead time in ETO operations [26]. Meanwhile, Al-Khafaji and Al-Rufaifi applied the Arena simulation tool to develop a pull system in an Iraqi leather company. The results found that production efficiency depends on the number of machines, production facilities, and workers' performance [27]. Zahraee et al. also implemented the VSM approach integrated with computer simulation to identify and eliminate waste in an electronics company [28].

The primary objective of the research is to display the application of a VSM-based approach and other tools utilized in aircraft maintenance processes to reduce maintenance service time, subsequently, to decrease maintenance costs of maintenance services. The result illustrates the use of VSM in enhancing the PCE of maintenance services provided [17]. Rohani & Zahraee applied VSM to the color industry's production line progress as a case study. Established on the future VSM, the result demonstrates that production lead time (PLT) reduced from 8.5 to 6 days, and VA time decreased from 68 to 37 minutes by applying lean techniques. In order to achieve this goal, LM of fundamentals was taken to assemble VSM to identify and eliminate waste by teaming, development selection, idea design, and time- formulation through takt time calculation [29]. Vo and Nguyen conducted research using lean production on a Surface Mounting Technology (SMT) line in an electronics company in Vietnam. Implementing Lean tools could eliminate downtime in production and achieve efficiency in productivity and quality, as well as reduce the number of workforces, raw material consumption, and production cost [8]. Some Lean techniques commonly applied in the production line include VSM, 5S, U line layout, skilled workers, Kanban, Push and Pull system, etc. [30-32]. Even though it is true that these techniques can enhance the operational performance and production costs in companies [33], they might not be proper for all firms due to the different characteristics of each company and environmental elements (i.e., company size and culture) [34].
Therefore, LM implementation begins with the development of VSM and is shown clearly in Section 4.

3. Methodology

This section aims to provide the proposed methodology for improving the production line. The method consists of five main steps, shown in Figure 1.

The first step is to select the main product family, which significantly impacts the organization's efficient production operation. In this step, the production activities will be observed and evaluated at the workshops at a specific time. Shifts per day, hours per shift, break minutes per shift, customer demand, cycle time, operators, and WIP of each stage will be collected. SIPOC (suppliers, inputs, process, outputs, customers) chart will be utilized in this stage. A SIPOC diagram is a visual tool for presenting a production process from the first stage to the end before implementation. The second step is to analyze and identify existing problems. Based on collected data, the current VSM has been analyzed to determine the existing issues (such as unbalanced workload, over-processing high inventory, and so on) on the production operation or production line. In this stage, the VSM tool simulates all operations from the logical model to identify the production line's waste. Then, Lean tools will be proposed to improve the current situation in the third step. These tools, such as rebalancing production line, Kanban card, and 5S, will be employed for continuous improvement. The fourth step aims to establish future VSM based on the suggested improvements in the previous step. The improved actions for designing a future-status map include setting up a continuous flow, experiencing a process with smoother without returns, and producing products in the shortest lead time, highest quality, and lowest production cost.

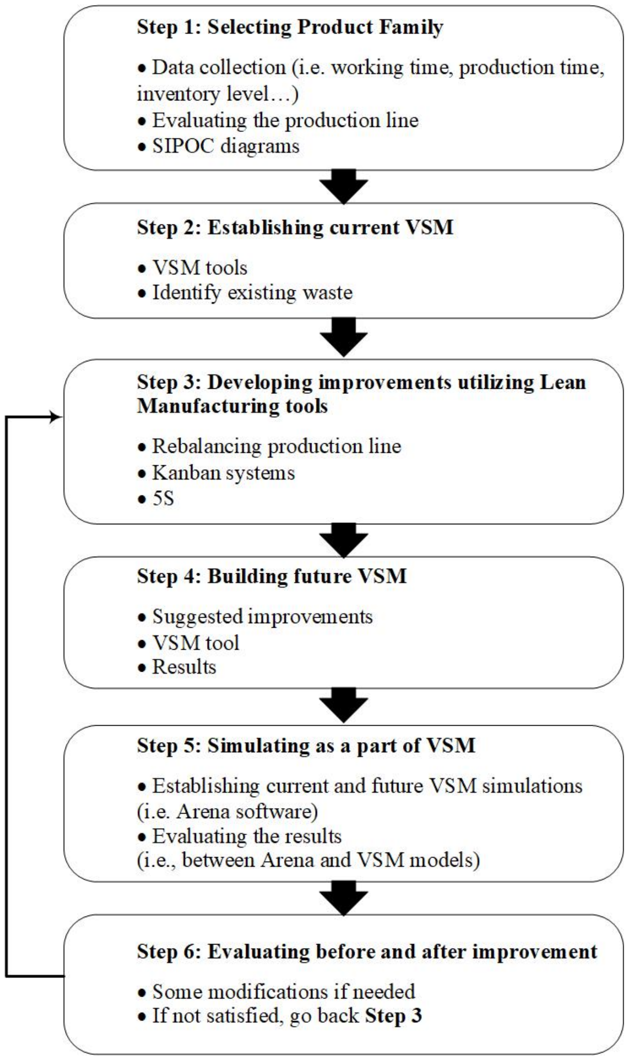


Fig. 1. Methodology of implementation research.

The next step is to evaluate and compare processes before and after improvements via Arena models. The last step is to evaluate and compare processes before and after improvements. Some modifications will be implemented if needed. If the results do not meet the company's expectations, the procedure is required to go back in steps to proposed tools.

4. Case study

This paper aims to be designed for practicing and producing products for studying and living activities, such as desks, chairs, beds, computer desks, boards, and toxic fume hoods at School Equipment Workshop, College of Engineering Technology, Can Tho University. The workshop has been equipped with more modern machines and specialized lecturers teaching, researching, and practicing at the school to create a professional and versatile operating environment. The study selected the company as a real case study to prove the proposed method using lean tools and simulation.

4.1 Selecting the primary product

This paper focuses on the survey and improving the computer desk's manufacturing process. The computer desk is the primary product line; TP-BVT-03 is the critical product of the TP-BVT product line. To apply the VSM to the computer desk's production process at School Equipment Workshop, College of Engineering Technology, Can Tho University, it is necessary to understand the production process at each stage to build a VSM sensibly. This product was chosen to streamline the production process is shown in Figure 2 as follows:

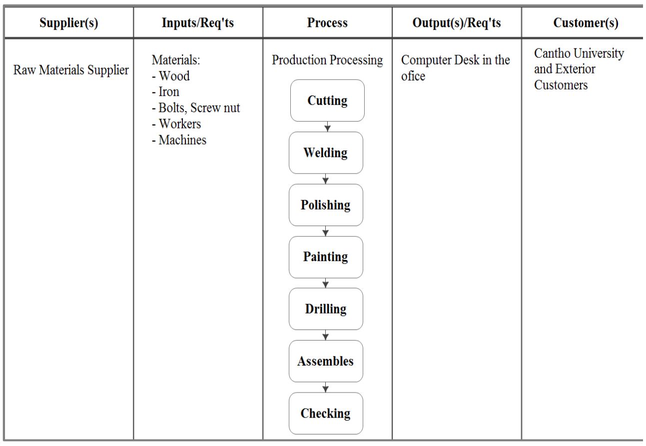


Fig. 2. SIPOC Computer desk's production process diagram.

School Equipment Workshop, College of Engineering Technology, Can Tho University operates on a single eight-hour shift every day from 7 AM to 5 PM. The time between the mid-shift is 120 minutes. Availability production time (APT) can be defined as the time it takes to build a product from start to finish [35]. The output data is collected, namely Cycle Time (CT), Operator (OP), Takt Time (TT), Up Time (UT), and Change Over Time (CO). Then, data are calculated, such as:

APT = 8 x 3600 = 28800 seconds

$$\text{Takt Time} = \text{APT} / \text{Daily demand} \quad (1)$$

$$= 28800 \times 6/ 140 = 1234 \text{ seconds/ piece}$$

$$\text{AOP} = \text{APT} - \text{CO} \quad (2)$$

$$\text{UT} = \text{AOP}/\text{APT} \times 100\% \quad (3)$$

The production process of seven workstations is contained in Table 1. Based on the customer needs, each station's inventory level and time are shown in Table 2.

4.2 Establishing current VSM

This step aims to analyze and identify existing problems in the production line. Based on the current situation shown in Table 1 and 2, the current VSM is established (shown as Figure 3). The VSM is a process of creating a product from raw materials to the preservation step. Process parameters of the current VSM (i.e., lead time, value-added time (VAT) and raw materials (RM), Process Cycle Efficiency (PCE), WIP and inventory time are summarized in Figure 3.

Table 1. Current state process date of workshop.

Station	Cutting	Welding	Polishing	Painting	Drilling	Assemble	Checking
CT (sec)	295	1550	540	2595	476	570	861
CO (min)	504	656	600	700	432	672	372
APT (min)	2880	2880	2880	2880	2880	2880	2880
AOP (min)	2376	2224	2280	2180	2448	2208	2508
UT (%)	82.50%	77.22%	79.17%	75.69%	85.00%	76.67%	87.08%
OP (person)	1	2	1	2	1	1	1

Table 2. Inventory level and inventory time of WIP in process data.

No.	Stage	Inventory (products)	Inventory time (hour)
1	Material warehouse	80	34.3
2	Before Cutting	160	0
3	Prepare Cutting	140	0

4	Cutting	0	0
5	Welding	0	0
6	Polishing	0	0
7	Painting	10	10.5
8	Drilling	0	0
9	Assembling	0	0
10	Checking	2	1.69
11	Finished product	128	0

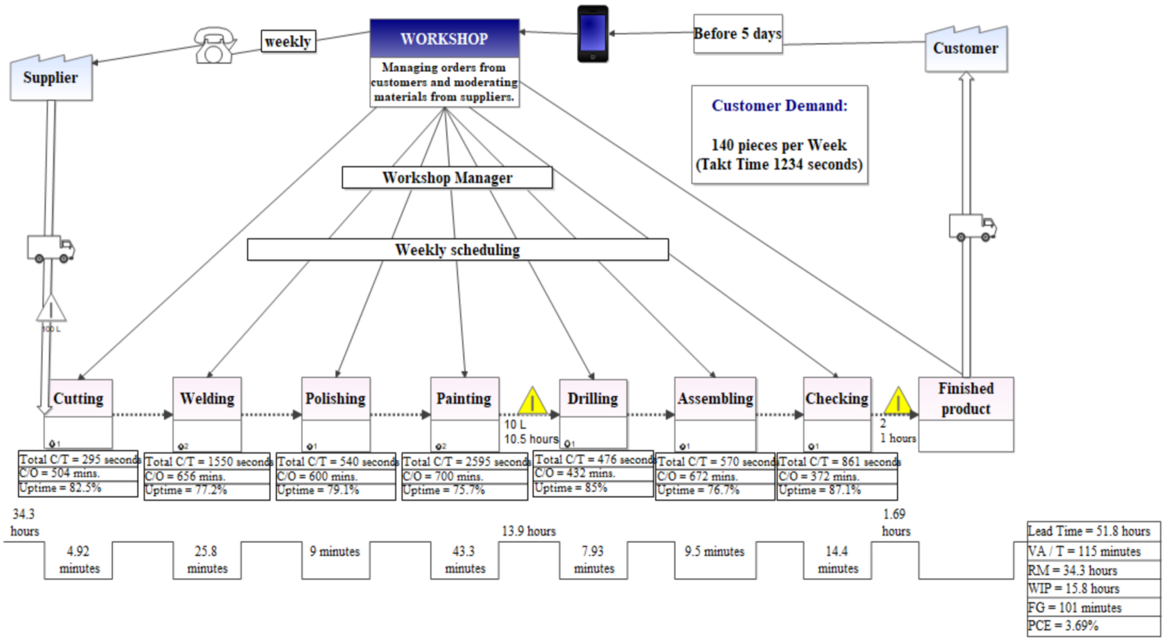


Fig. 3. Current VSM.

The results showed that the current process has high WIP (15.8 hours) and high inventory time (11.5 hours). Hence, PCE is remarkably miserable, at only 3.69%. Through primary analysis, the imbalance of workers, unqualified schemes, and unreasonable assumptions are the leading causes.

Takt time is significantly higher than some workstations (i.e., cutting, polishing, drilling, assembling, and checking workstations). This indicates that the manager needs to understand the capacity of the production line. Besides, the execution time at Painting and Checking is high, and the remaining stations need to be increased than takt time (shown in Figure 4). The human resource adjustment is unreasonable, so it is necessary to balance the line.

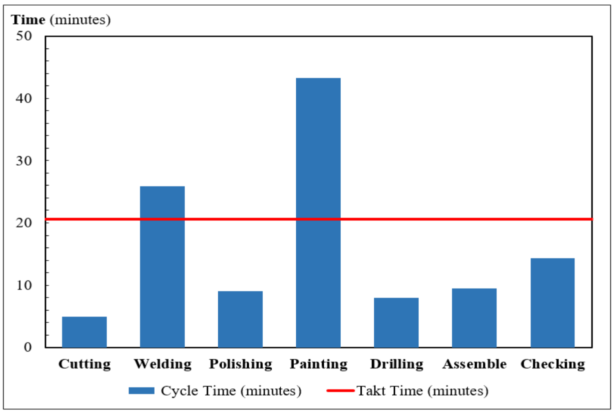


Fig. 4. Time of workstation in current state.

The problem of the workshop is that the painting process has a high cycle time, as shown in Figure 4, because it bottlenecks at that stage; the CO time is too significant between the steps, causing WIP time in the painting and checking workstation (WS). As a result, the production line will face inventory problems when the order is completed. Therefore, this study applies the Kanban tool and inventory shelves to reset the system for the line to reduce WIP in production. Especially, applying for Kanban FIFO cards at Painting WS aims to reduce WIP and inventory time.

4.3 Developing improvements utilizing LM tools

After analyzing the current VSM, Lean tools have been applied, such as Kanban, inventory shelves, and Kanban FIFO cards, and the rebalancing process to reduce waste and increase the line's efficiency in the short term.

4.3.1 Applying process balancing

From the workstations' production time diagrams, the cutting station's production time is faster, so connecting Cutting to Welding WS reduces one worker. After rearranging the process, the production time of polishing and drilling WS was speedy, so combining polishing with drilling WS contained two employees. Painting WS has an extended production time and needs to be arranged for one more worker to increase productivity. The cycle time and the number of laborers after rebalancing are shown in Table 3.

Table 3. The cycle time and number of labors after rebalancing.

Workstation	CT (sec)	CO (min)	APT (min)	AOP (min)	UT (%)	Operator
Cutting Welding	1845	504	5760	5256	91.25	2
Polishing Drilling	1016	432	5760	5328	92.50	2
Painting	3892	700	8640	7940	91.90	3
Assembling	570	672	2880	2208	76.67	1
Checking	861	372	2880	2508	87.08	1

4.3.2 Using Kanban and inventory buffer

From the current VSM, Painting WS has a high production time (2595 seconds), and the demand is 140 computer desk products per week (with takt time is 1234 seconds). Therefore, WS Painting is the bottleneck in this production process. For the future VSM, instead of only Cutting WS receiving orders from the leader, the charges will be transferred to each WS through the production Kanban card, as shown in Figure 5 below.

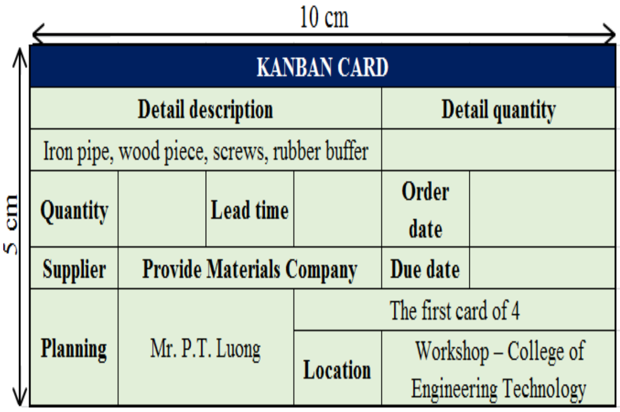


Fig. 5. Described Kanban card.

In addition to using inventory shelves at the receiving raw materials and finished product warehouses, inventory buffers have been used for cutting and welding WS, polishing and drilling WS, and assembling WS to make a Pull system from customers. The Kanban's moving path diagram is shown in Figure 6 as follows:

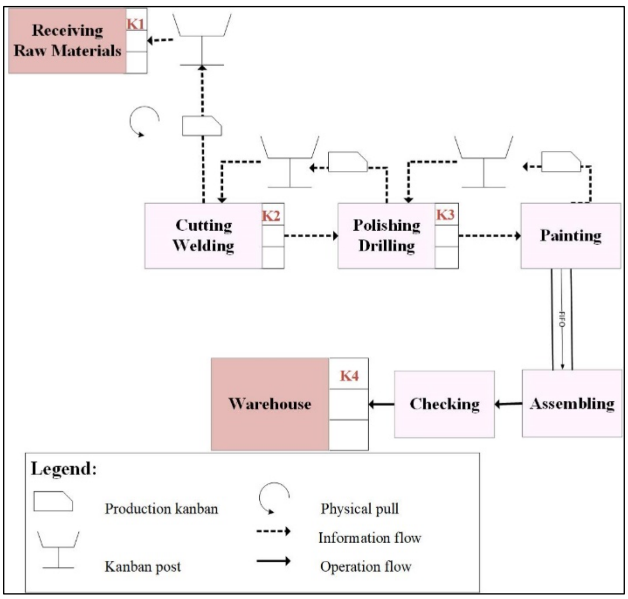


Fig. 6. The Kanban's moving path.

- The K1 inventory shelves is placed in front of the welding and cutting station to receive raw materials from the supplier upon order from the customer. The cutting WS will produce the following customer needs 140 products, and Kanban production cards will be used to get raw materials from the K1 inventory buffer. At the same time, the corresponding Kanban card will also be put in the Kanban card box and sent to other production departments to correspond with the number of used materials.
- The K2 WIP inventory shelves is set up between cutting and welding WS and polishing and drilling WS. Kanban cards from cutting and welding stations are produced to get semi-finished products from K2 on demand. Then, transmitting production orders to polish and drilling stations has been applied.
- The K3 semi-finished products inventory shelves is between polishing and drilling WS and painting WS. Kanban cards from Painting WS are produced to get semi-finished products from K2 on demand. The painting WS has a long cycle time and produces considerable quantities; Kanban cards transfer production orders to polishing and drilling WS.
- Semi-finished products after the painting station will be pushed into the FIFO inventory flow.

4.3.3 Applying 5S

To reduce waste in the production process and build the most profitable future VSM, 5S tool has been proposed to improve the working environment and implemented in 2 periods:

Phase 1: Sort – Set in order - Shine

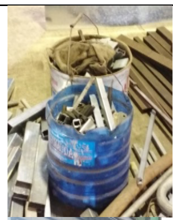
During this period, implementing 3S was proposed in working areas at the workshop. Sort is the simple act of removing items from a location. If something is unnecessary and doesn't add value, it should be removed from the area. Seiton is all about building a good workflow. The items in the workspace are in their optimal positions where a worker standing at that workstation can access them without moving. Seiso is all about maintaining the space. Keep it tidy and keep it clean.

Phase 2: Standardize - Sustain

During this period, the division of labor is scheduled to carry out 3S in the workshop and tabulate to evaluate the level of 3S laborers' performance. Thence, put forward a reward policy for laborers who perform well.

Before and after improvement of 5S at the workshop is shown in Table 4 as follows:

Table 4. Before and after improvement 5S.

Hygiene Method	Before	After
It is defining materials that need to be eliminated. Sorting material again to know what laborers can keep using or not. Collecting work instruments to put them in the same area. Be tidy up again.		
Defining the object and workstation need to be clean. Types of machinery are rearranged in the correct position so as not to waste time. Cleaned machinery and rechecked lubricating oil for machinery applied.		

4.4 Simulating as a part of VSM

After using Arena software to simulate current and future VSM, the result and realized the production time of 140 products is shortened by approximately 11 hours (as shown in Figure 9) to prove the improvement brings effect. For this reason, this research should apply all activities in the workshops.

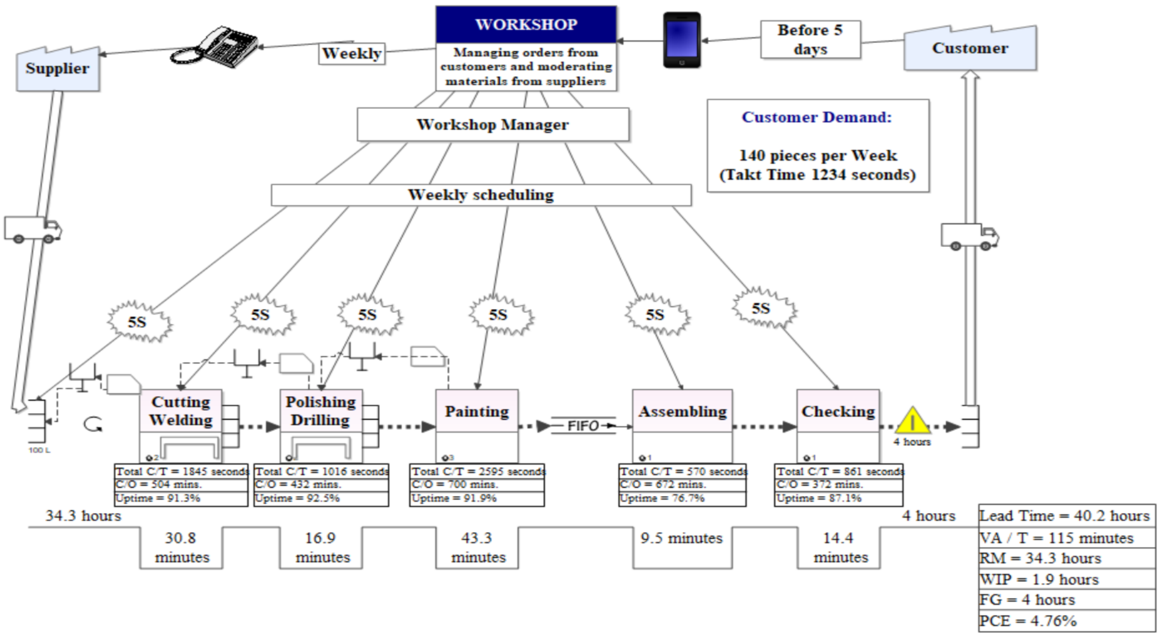


Fig. 7. Future VSM.

The processing time was reduced by 11.6 hours (from 51.8 to 40.2 hours), WIP of inventory time decreased by 13.9 hours (jumping 88% improvement), whereas there has been a noticeable improvement in the PCE ratio jumping from 3.69 to 4.76%. It is said that inventory time in the production process has been reduced and improved efficiency.

4.5 Simulating as a part of VSM

The simulation model is simulated by Arena software to analyze data. Supposing the whole process is an uninterrupted flow that skips the laborers' interruption, and the engine breaks down. The replication length is 48 hours, and the number of replications is five times. Set up input of raw materials in 295 seconds and order for140 products per week. The time to set up the simulation model at every workstation is shown in Table 5.Current and future VSM simulations are expressed in Figure 8 following.

Table 5. Simulations run time

Step	Current		Future	
	Function	P-value	Function	P-value
Cutting	NORM(296, 0.308)	0.15	UNIF(900, 947))	0.0689
Welding	TRIA(1.54e+003, 1.54e+003, 1.56e+003)	0.135		
Polishing	535 + WEIB(7.08, 1.93)	0.139	UNIF(1e+003, 1.09e+003)	0.0503
Drilling	460 + GAMM(4.29, 1.43)	0.149		
Painting	UNIF(2.55e+003, 2.59e+003)	0.062	UNIF(1.25e+003, 1.35e+003)	0.355

Assembly	UNIF(460, 475)	0.237	UNIF(460, 475)	0.237
Checking	NORM(855, 2.6)	0.005	NORM(855, 2.6)	0.005

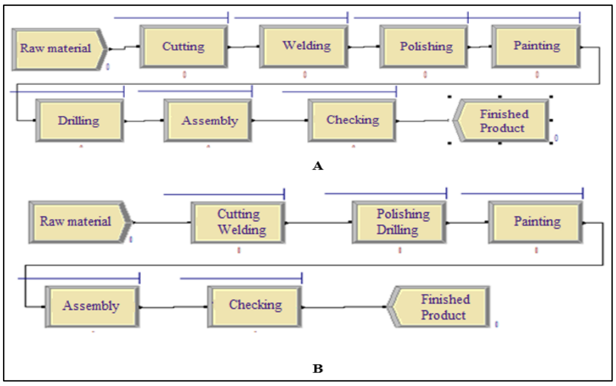


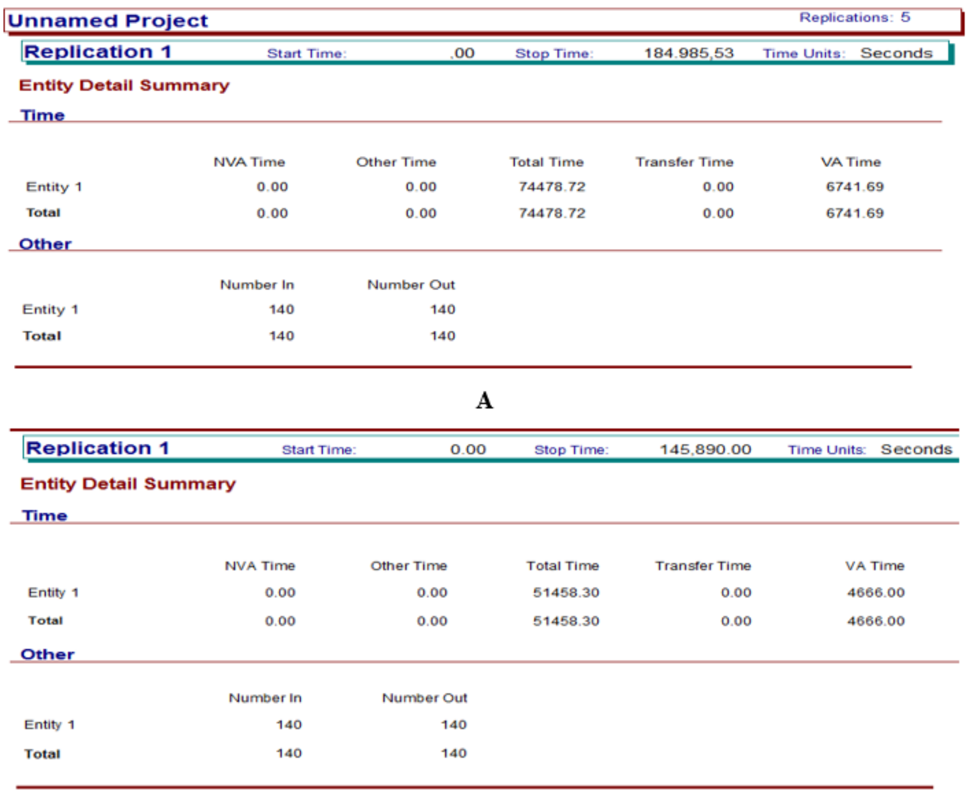
Fig. 8. Arena model of producing line: *Current VSM (A) Future VSM (B).*

After using Arena software to simulate current and future VSM, the result and realize the production time of 140 products is shortened as Figure 9 from 186.803 seconds to prove the improvement brings effect. For this reason, this research should apply all activities in the workshops.

4.6. Evaluating and comparing processes before and after improvements

After establishing the current and future VSM, this research has achieved the following results at Table 6.

Production time is reduced from 51.8 hours to 40.2 hours (about 22%), whereas the efficiency of the production cycle increased significantly from 3.69% to 4.76%. Especially, painting WS with considerable WIP time has been significantly decreased, and inventory time markedly improved from 11.5 hours to 4 hours (approximately 70%). However, some results did not meet the factory's set objectives, such as RM time remaining 34.3 hours, whereas WIP time has been abnormal increase by over 88%. Therefore, the Kanban information (K4 inventory shelves) at Assembling WS and Checking WS is applied, as shown in Figure 10. FG from painting WS will be prioritized handle at the assembly station. The production line has a pull system from the end station.



B

Fig. 9. Entity detail summary current VSM (A) future VSM (B).

Table 6. Comparative of effective current VSM and future VSM

Criterion	Current VSM	Future VSM
Lead Time (hour)	51.8	40.2
Inventory time (hour)	11.5	4
PCE (%)	3.69	4.76
WIP (hour)	15.8	1.9
RM (hour)	34.4	34.4
FG (minute)	1.69	4

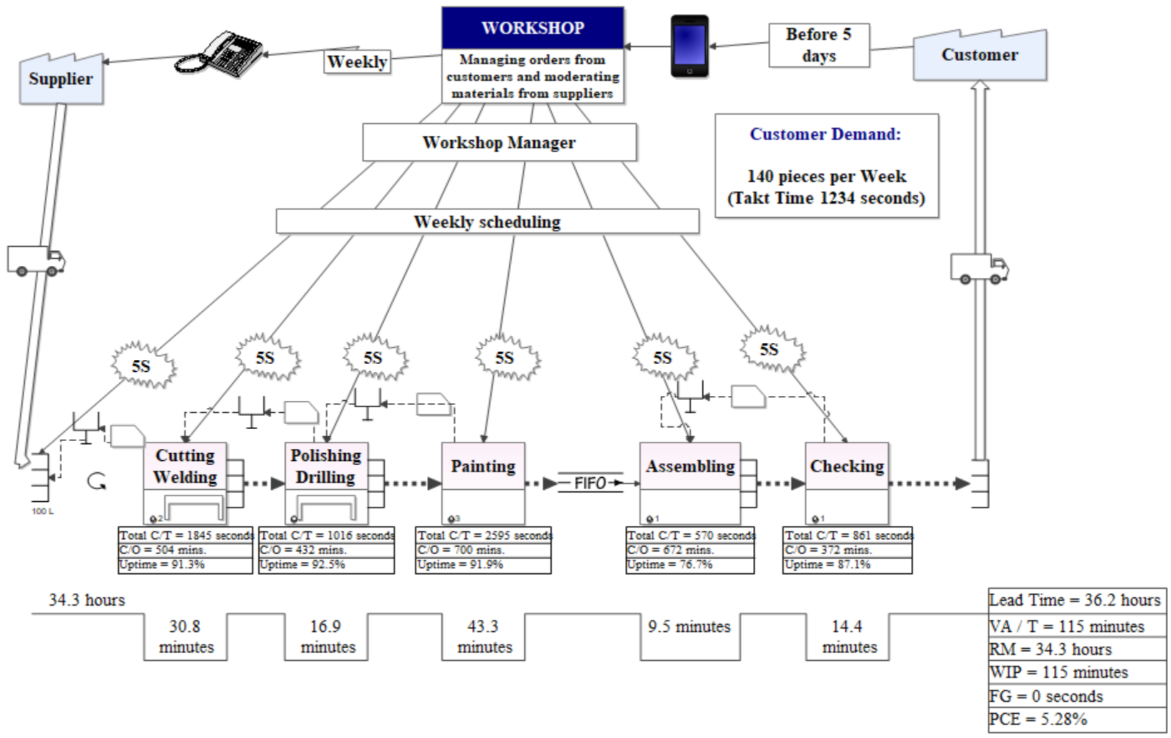


Fig. 10. The future VSM after the second improvement action.

5. Results

This case study illustrated considerable improvements through the leanness assessment using VSM, rebalancing line, Kanban tool, and 5S. Eliminating different types of waste has enabled the organization to increase PCE without requiring additional resources (9 operators throughout the improvement process).

5.1 Reduction of WIP inventory

The three most important types of inventory are raw materials (RM), WIP inventory, and FG times. After establishing the current and future VSM, this research has achieved the following results at Table 6.

Table 7. Comparative of effective current VSM and future VSM

Criterion	Current VSM	First future VSM	Second future VSM
Lead Time (hour)	51.8	40.2	36.2
PCE (%)	3.69	4.76	5.28
RM (hour)	34.4	34.4	34.4
WIP (hour)	15.8	1.9	1.9
FG (hour)	1.69	4	0

Production time is reduced from 51.8 hours to 36.2 hours (about 30%), whereas the efficiency of the production cycle increased significantly from 3.69% to 5.28%. The results show a noticeable effect when applying the Kanban system to production. Exceptionally, FG time has been dramatically dropped by 100% after applying Kanban card at Assembling WS and Checking WS. Besides the results, there are also limitations of the production line through RM time. However, the RM time has remained the same because this workshop has yet to invest in the materials problem. They still use the traditional push system for this WS.

5.2 Limitations of the production line

Significantly, selected elements can be changed to any level without further investment. The case company can carry out future VSM to achieve Lean production without financial pressure. This can be the first step towards attaining LM. According to the promising results, the proposed methods are also readily applicable to similar industries. Due to their excess productivity and time, some workers will help in the following stages to limit idle time, extra efficiency, and reduce WIP for the next steps. From there, making the most of resources and operating efficiently must eliminate waste for many reasons. Some existing problems have been found, such as a lot of idle time, a high failure rate leading to a longer delivery time, and a small number of orders. This increases inventory costs, affecting the profitability of supply chain components. Therefore, some innovative solutions have been devised to solve the above problem.

6. Conclusions

This research aims to identify inventory time through VSM, a critical tool in LM. The study has achieved the following results, such as 1) identifying inventory waste through the current VSM, 2) applying rebalance line, Kanban system, and 5S to reduce the waste on the production line, 3) evaluating and comparing processes before and after improvements via Arena models, and 4) establishing future VSM through proposals. As a result, PCE was increased by more than 30% compared to the current system (from 3.69 to 5.28%), whereas the inventory time has been reduced by approximately 90% (1.95 days).

Many factories and companies are interested in activities that create direct value without regard to the waste in the production process. Wastes can directly affect productivity and performance, thereby affecting product creation time. On the other hand, intangible costs are derived from wastes that cause a significant loss of production costs. Therefore, managers need to pay attention to regular improvement by applying VSM value chain diagrams to identify production wastes, arranging, and redesigning processes, applying innovation with lean tools, and applying modifications to many different manufacturing processes. The waste can directly affect productivity and performance, affecting product add-valued time.

On the other hand, intangible costs are derived from wastes that cause a significant loss of production costs. Therefore, managers must pay attention to regular improvement by applying VSM to identify production wastes, arrange and redesign processes, innovate with lean tools, and modify many different manufacturing processes. Limitations in the production line, such as the inappropriate distribution of workers, and the working environment, significantly affect workers' health because these jobs are heavy. Therefore, future studies will focus on implementing lean technology for a pilot production line instead of just implementing a Lean tool called Kanban.

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