ASEAN Engineering Journal

Full Paper

TRANSFORMER PRODUCTION IMPROVEMENT BY LEAN AND MTM-2 TECHNIQUE

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Article history
Received
17 March 2021
Received in revised form
24 January 2022
Accepted
10 February 2022
Published online
31 May 2022

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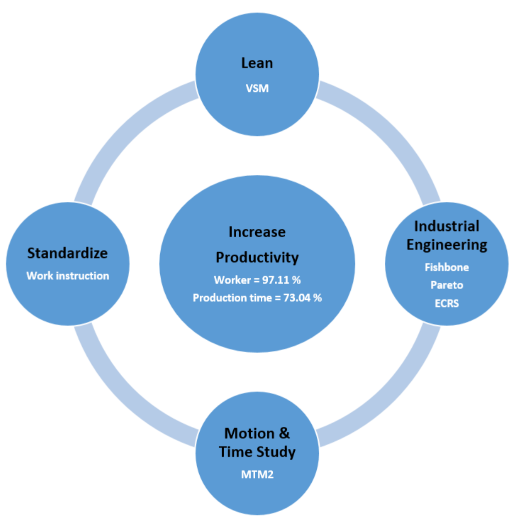
Graphical abstract



Abstract

The situation of the covid-19 epidemic is a driving force of the global market's demand increase of electronic devices and parts. Entire electronic component manufacturers, especially the transformer manufacturing industry, which is a device that supplies power to many electronic devices, encounters problems in producing products that are unable to keep up with the quickly increasing demand. This research aims to increase the productivity of small transformers by lean approach. The paper depicts processes relevant to improving production processes, reducing waste, and finding unnecessary processes. The method begins with two actions. First, study the current situation in transformer manufacturing of a case study. Second, study the customer order to delivery process using the Value Stream Mapping (VSM) and analyze entire processes of transformer manufacturing to identify standard time by unit work. The main technique is for measuring working time by timing the forward motion with the time measurement method version 2 (MTM-2). The Cause and Effect diagram was displayed with improving guidelines on two operations. First the concept of lean manufacturing was used in principal role, second the ECRS technique (Eliminate, Combine, Rearrange and Simplify) was applied to reduce "waste" as well as to optimize and reduce the manufacturing process of the transformer. The results lead to an increase in the final product per hour from 45 pieces per hour to 75 pieces per hour which increases up to 30% per hour. In addition, the productivity improvements increased the productivity of 3.46 workers per hour to 6.82 per hour (increase of 97.11%) and production time was reduced from 1,109 seconds to 229 seconds (73.04% of productivity).

Keywords: Lean Manufacturing, Value Steam Mapping (VSM), ECRS technique, Method Time Measurement version 2 (MTM-2), Labor Productivity

1.0 INTRODUCTION

The electronics component production industry plays a very significant role in obtaining national income especially, in the pandemic crisis of Covid-19 in 2020 [1]. Consequently, there is a demand for utilizing electronics components such as communication equipment, mobile devices, etc. Therefore, companies that produce electronics components all around the world are required to improve and develop their production process continually, control and maintain the product quality, and also manage the production cost precisely to be able to accommodate the national and international demand [2]. Most electronic goods are devices with installed transformers.

A transformer is a passive component that transfers electrical energy from one electrical circuit to another circuit, or multiple circuits. Hence, the higher demand for electronic devices, the more demand for the transformers. In Thailand, human labor plays an important role in many electronic manufacturing industries. Most small and medium unit producers usually face the problem with low productivity in production processes due to the cause of workers lacking skill making the small and medium producers face line production problems [3]. For instance, the area workspace of the workers on the production line and also the problem of messy production areas that obstruct workers movement while working [4]. For this reason, the workers will always be strain and fatigue affecting the production and failing to work according to plan. Therefore, production engineers and production management have to solve the problem by identifying waste and non-value add processes throughout the entire operation. Because these problems will be a reason for the business not being able to produce and deliver the product to the customers on time. Most literatures, the Lean approach, VSM (value stream mapping) technique and motion time study were used to improvement in production process.

Lean manufacturing as a set of concepts, principles, methods, procedures, and tools geared towards the improvement of the production flow by reducing waste. The simple principle is identifying value-added processes and those that do not add value to a company, and the just-in-time production method that is presented by some connoisseurs and interested in the field in Romania [5]. Lean manufacturing can be used as a good strategy of process improvements and an alternative to increase the production output without a big amount of investment [6]. Lean is considered as a major management approach for improving operational productivity and organizational performance, the applied lean management principles in making sense of the transformation processes involved in the use of digital innovation in higher education context. The findings provide a holistic view of the process transformations [7] Lean-Kaizen means continuous elimination of wastes through small-small improvements. The implementation of Lean-Kaizen concept in a small- and medium-scale enterprise (SME) at a non-capital region in India by Kaizen events, reduced inventory level, reduced lead time and reduced cycle time, rework elimination, improved productivity, and improved product quality were achieved [8]. The kaizen events for productivity improvement in a printing company that organize lean tools to improve productivity through the use of organized kaizen to meet defined targets [9].

In the lean approach, the VSM can be highlighted since it provides a holistic view of manufacturing processes and has become one of the most used tools in the applications of lean thinking in industrial and service companies. VSM is a dominant tool that helps an organization to improve the understand towards lean. A successful lean implementation was recorded in context to Indian case study is an attempt to implement the Lean-Kaizen concept using VSM in order to tackle all types of inefficiencies and wastes. The study reported benefits such as reduction in machine setting time, manpower, production lead time and value-added time which smooth production and ease working condition of the industry [4]. The implement VSM in axle beam housing processing line to reveal obvious and hidden waste could reduce the lead time with able to up productivity [10]. The identification of waste or MUDA [11] based on the seven kinds of waste, known from a lean context [12], that affect the quality and productivity of the products. Improvement process under Lean Manufacturing tools, for increase the performance in the value chain [13]. Thus, the ability of the method to improve the overall productivity that the taken measures are expected to reduce the lead time [12], significant reduction of cycle time, after implementing the Kaizen event [13], and the personal cost of a tool exchange is reduced [12]. The VSM has been improved using 5W1H techniques and ECRS principles as solution to reduce of lead time and take an advantage of the remaining time to complete other orders without hiring more workers. Moreover, the effectiveness of the proposed classification system was evaluated by using the standardized classification system to measure the VA and NVA by VSM [6][14][15].

Motion and time study by the Methods Time Measurement version2 (MTM2) used to analyses human motions during work activity, and they are attempting to improve and optimize a given process [16]. For the example, the MTM was also used to conform to the economic principles of movement and work time measurement to improve the working system in order to get the standard time at the cement bagging station to reach the production target [17].

In this study, researchers studied and collected data from one small Japanese company in Lamphun province of Thailand which has the potential to produce transformers around 15,000 per day. This company is a branch of one Japan Company. The firm manufactures and sells semiconductors, electrical equipment and power supply products. The company has been operating for a long time and has many employees (around 1020). Researchers have a team that work for this company and hold a position as transformer line production executives who are able to decide experiments and decisions for this research. The study showed methods for improving production processes by reducing cost, time and waste, instead of increasing budgets by applying industrial engineering tools and Lean manufacturing approach [19]. All operations and procedures of transformer production in the case study firm were analyzed by principles of Lean with the time study measurement of workers by MTM2 technique [20][21][22]. The rest of the article consists of four topics: related work by literature review, materials and method, results, discussion and conclusion. Firstly, the theories and related works about lean approach and motion time study were studied. Secondly, the experiments by Lean approach and industrial engineering tools were used to estimate operations and processes. Thirdly, the results in the study showed that the improvement of the production process was able to eliminate "Waste" and "Non Value" in the transformer production and also increased the production capacity of the case study firm. As a result, the problem of delays was reduced in the manufacturing process and would help the company deliver products to customers on time. In conclusion, a summary explaining how to make new standards and methods for line production will lead to more potential in industrial competition continually.

2.0 METHODOLOGY

In this part, the Lean concept and industrial engineering tools were applied to gather data and evaluate all processes in transformer production of the case study firm. Figure 1 depicts the research processes and details described as follows.

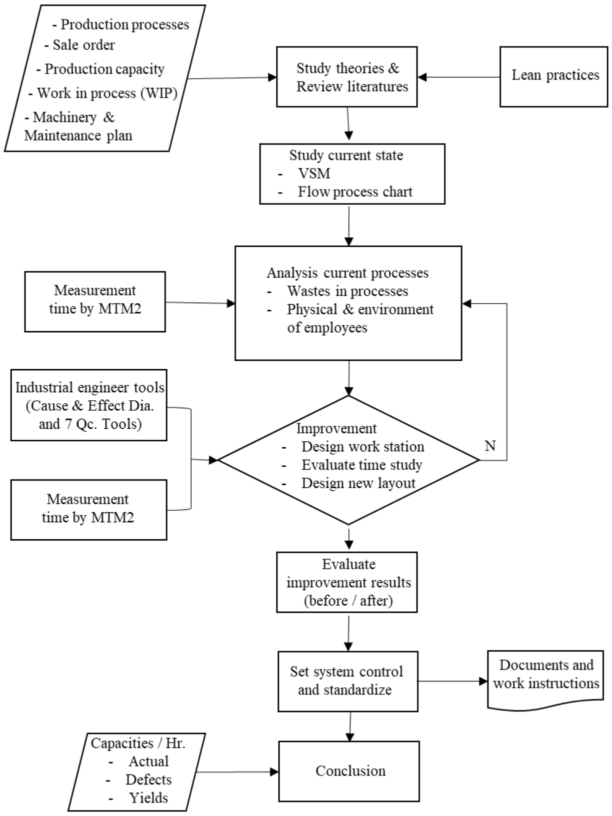


Figure 1 Flow Chart of Research Operation

Study of Relevant Theories, Concepts and Research Papers Including Primary Information of the Case Study Factory

Study was performed on relevant theories and details of research from relevant research papers on lean technical manufacture, books, articles, printed materials, reports, and online data. After that primary information of the case study factory was investigated, especially on principal working procedure and all procedures related to transformer manufacture, by using industrial engineering tools such as Current Value Stream Mapping, Flow Process Chart, and Cause and Effect Diagram.

Study of Present Work Procedure and Time of Manufacturing Process

Work procedure of transformer manufacture was studied by recording of motion time study. The observation was performed from the manufacturing preparation, coil winding, assembling preparation, gluing, transformer core assembly, power test, magnetic field leakage measurement, product logo pressing, and workpiece eyesight testing, so that this data could be used in the improvement and analysis.

After that work flow chart and present work operation were created using Process Chart. Manufacturing process was drawn with a Flow Diagram of the transformer manufacturing process. Data collection was performed to find working standard time by separating works into subordinate activities using improvement of PMTS (Pre-determined Motion Time System) technique with MTM-2 (Method Time Measurement version 2) which yielded acceptable accuracy level compared to its usage convenience.

Guideline Design for Production Process Improvement

After studying and analysis of work in small transformer manufacture by using MTM-2 (Method Time Measurement version 2), increasing production capability was emphasized through improvement of work and implementation of assisting machine equipment. The guideline consists of 3 main parts; 1) eliminating unnecessary work steps if there was a rearrangement of work order using 7QC Tools, 2) Data of movement during work was recorded for calculating time in MTM-2, and work process was improved to be less complicated to increase single piece flow efficiency by the observation from manufacturing preparation, coil winding, assembling preparation, gluing, transformer core assembly, power test, magnetic field leakage measurement, product logo pressing, and workpiece eyesight testing and 3) creating Line Layout for layout improvement operation in the assembly line to have an efficient workflow.

Calculating Standard Time and Productivity After Improvement

After the improvement, time data was collected to be assessed and constructed into work standard time of the studied procedure, and later became documents and operation manuals.

Operation Summary

It is a research summary using data and study results collected from the operation process. The results were then gathered and compared with the data before and after the improvement. This data would be proposed as a guideline for future operation of other work sections.

3.0 RESULTS AND DISCUSSION

The study performed an experiment of improving the transformer Model CT-XXXX (Figure 2). The transformer production procedure begins from preparing the carbon core by putting in the insulator for supporting coil. The coil is rolled to be cut in pieces by the machine. After that both edges of the copper coil are cut into preferred length then it is taken to chamfer the insulator covered by copper until it turns pure copper at the edges of the copper then dip Tin on the legs of the coil and fold the leg with Jig. The completed piece of the coil will be put into the power inductor in a transformer and it is connected with glue between the carbon core and the coil. After the glue dries then glue it again to ensure that it is well built. Finally, inspect the inductance of the coil then use it to inspect the transformer's electricity.

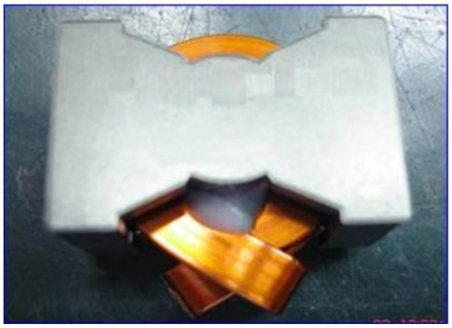


Figure 2 Transformer Model CT-XXXX

Value Stream Mapping of Transformer factory – As is

In the study, researchers collected 2 types of data; 1. Primary Data collected from interviewing workers and also from the observation of the actual operation. 2. Secondary Data gathered from documents, relevant reports then used for constructing the Value Stream Mapping for indicating current state mapping of the factory that is the case study. The operation of all the case studies would have 7 subordinate activities (see figure 3). The operation started from; every month the factory received the orders from clients then planned the production and materials purchase. Each day, the materials would be delivered to the factory and after that it would be transferred to each department following the purchase plan. The analysis of all the current operations from Value Stream Mapping showed that the performance of the workers in the process with draw materials needed to be improved. As the process time in the production was 79.12% of the transformer production, therefore, the production process needed to be improved applicably. However, the analysis from the current 10 subordinate activities showed that the analysis value capacity was identified to be the 3 activities of Value – Added: VA and 7 activities of Necessary Non-Value Added: NNVA (table 1). The average time of Value – Added was 38.75 hours or 10.49% of all activities and the average time of Necessary Non-Value Added: NNVA was 330.75 hours or 89.51% of all activities (table 2).

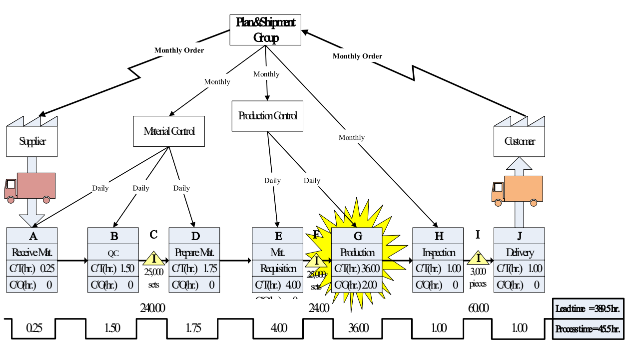


Figure 3 Value Stream Mapping - As is

Table 1 Overall Process of Operation and Average Time in Each Step

Activity	Definition	Average time (Hour)	Type of activity	Value Analysis
A	Receiving Raw materials	0.25	Operation	NNVA
B	Quality Assurance	1.50	Inspection	NNVA
C	Keeping Raw materials in Warehouse	240.00	Storage	NNVA
D	Preparing Raw materials	1.75	Operation	VA
E	Taking out Raw materials	4.00	Operation	NNVA
F	Keeping Raw materials at preparation area	24.00	Storage	NNVA
G	Production	36.00	Operation	VA
H	Quality Assurance	1.00	Inspection	NNVA
I	Finished goods	60.00	Storage	NNVA
J	Transport	1.00	Operation	VA

Table 2 Activities Analysis of All Processes

Activity	Time) hr.(	Percentage
VA	38.75	10.49
NNVA	330.75	89.51
Total	369.50	100.00

Value Stream Mapping of Transformer Line Production – As is

The study of Value Stream Mapping in the present-day has revealed that the operation involving workers' performance in the transformer production process needs to be improved. Therefore, researchers have studied Value Stream Mapping. The method was dividing all activities into 14 subordinate activities. In the beginning, the factories would receive the order from clients. After that the factory would do the production plan and purchase raw materials because each day the raw materials would be delivered to the factories and transferred to each department then the warehouse department would take out the raw materials to the transformer production department. Lastly, the factory would submit the pieces of work (finished transformers) to the inspector department. The entire process took approximately 36 hours (figure 4).

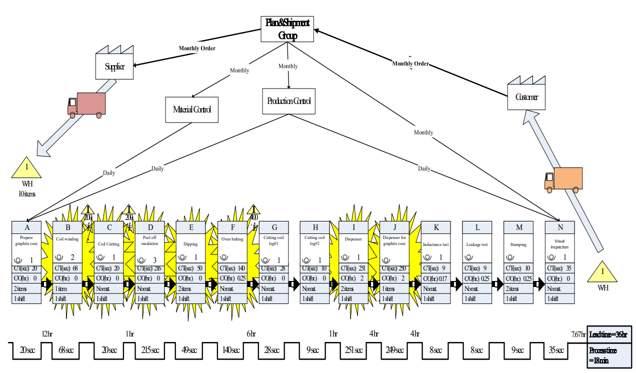


Figure 4 Value Stream Mapping - As is

Production Process Study

In this step, researchers studied each working procedure and determined standard time in each step with Method Time Measurement 2 (MTM-2) technique which helped determine the cause of delay and the problem in production performance. The analysis details of the transformer production process are shown in table 3.

Table 3 Analysis Process of Small Transformer Production

Activity	Problem (Non – Value Added)
Winding coil	Over processing from assign 1 of operators to hold copper coil roll for tightening coil.
Cutting	Waiting time from process of cutting coil because it is too hard and needs to apply force of grip to cut it.
Peel-off insulation	Low efficiency from excessive movement of this process and risk of accident from inappropriate tooling
Dipping	After analysis of work and motion movement by MTM-2, it was found that there is small time in dipping process, but operators dip only one piece per time.
Dispenser	Waiting time from dispenser 1 process for adhesive graphite core, operators need to wait until the adhesive is dry. Then dispenser 2 process can start

Time Study on Transformer Production Processes

The time measurement by MTM-2 (Method Time Measurement version2) was used to calculate time in this section. The standard time for each production procedure is shown in table 4. The table shows the data of regular time and the standard time of each production procedure that was received from the determination in every production procedure.

Table 4 Result of Calculation of Standard Time in Each Process Step Before Improvement

No.	Process	Normal Time :NT TMU	Normal Time :NT Second	Allowance Time: A %	Standard Time: STD Second
1	Preparing graphite core	483	17	13 %	20
2	Coil winding	1,622	59	13 %	68
3	Coil Cutting	463	17	13 %	20
4	Peel-off insulation	5,151	185	14 %	215
5	Dipping	1,180	42	15 %	49
6	Oven baking	3,295	119	15 %	140
7	Cutting coil leg#1	664	24	15 %	28
8	Cutting coil leg#2	235	8	15 %	9
9	Dispenser	5,922	213	15 %	251
10	Dispenser for graphite core	5,886	212	15 %	249
11	Inductance test	204	7	15 %	8
12	Leakage test	206	7	15 %	8
13	Stamping	234	8	15 %	9
14	Visual inspection	797	29	15 %	35
		Total			**1,109**

The Improvement Steps in the Transformer Production Process.

Researchers eliminated non-value added works and reduced tasks that were the reason of fatigue workers in transformer line production. All methods and results of improvement activities are depicted in Table5.

Table 5 Details of Improvement in Transformer Manufacturing Process

Activity	Method	Result
Coil winding	ECRS techniques were applied to help analyse the process by cutting out unnecessary procedures that required one employee to hold the wire roll, improving the wire table to support the coil and using a wire clamp to increase friction while the wire wrapper pulls the wire. Keep the wire tight.	After analysing wire wrapping using the workflow with a time-based study, MTM- 2 was found to have four difficult PC-levels, GW and PW weight lifting were used. After improvement they can remain in two PC-levels and without lifting the weight.
Activity	**Method**	**Result**
Coil Cutting	Study the process and combine operations by creating a pin cutter and changing the sequence of operations to make it easier for the machine to press the work piece in one operation.	After analysing the cutting of the wire leg using the workflow with a time study model, the time-based study, MTM-2, it was found to have a hard PC step 3 times after the improvement, no more difficult PC steps.
Peel-off insulation	Study the process and eliminate the non-value added works that required employees to scrape the wire with inappropriate tools. It caused the risk of accidents. Work fatigue and employee shortage or resignation problem.	After analysing the wire leg scraping using the time-based study, MTM-2, it was found that there were 13 difficult-to-effort PC steps. After the improvements for the hard-to-use PC-level, there were only 2 steps left by preparing a wire polisher, as well as designing a jig that would support the wire. The easy-to-determine direction, as well as the vacuum cleaner from polishing, has adopted the ECRS technique to reorder the workflow.
Dipping	After analysing the tin plating work using the	After the improvement of the hard-to-use PC-level

Activity	Method	Result
	MTM-2 time study, there were two difficult PC-level steps.	by improving the existing tin furnace to be used appropriately, as well as designing a jig that supports the wire while plating the tin legs, ECRS technique were introduced to the process of plating the legs, leaving no waiting time for the fumes to be absorbed.
Oven baking	The analysis was performed and it was found that there was an unnecessary process of baking the work piece after tin plating	This process was cancelled because the baking process did not have a clear effect on the inspection of the insulation.

Activity	Method	Result
Dispenser	The analysis of the work and findings were that there was a waiting job from the 1st glue drops and the second glue instillation.	Workflow studies were conducted and operations were combined by improving the air pressure system by adding another air valve in the adhesive system. This made it easier to adjust the pressure within a single glue dispenser arrangement, which can continuously apply the 1st time glue and the 2nd time continuously and change the work order to make the work easier. Thus reducing the working time of employees adopting the ECRS technique to create a conveyor system with hot air system to reduce waiting times for the glue to dry completely before entering the production process in the next step.

Standard Time Calculation After Adjustment

The improvement process was able to reduce 2 working steps from 14 main steps before the improvement, therefore, there are only 12 steps after improvement that is shown in table 6.

Table 6 The Determination of Standard Time After the Production Improvement

No.	Process	Normal Time :NT TMU	Normal Time :NT Second	Allowance Time : A %	Standard Time: STD Second
1	Preparing graphite core	483	17	13 %	20
2	Coil winding	1,378	50	13 %	57
3	Coil Cutting	316	11	13 %	13
4	Peel-off insulation	555	20	13 %	23
5	Dipping	619	22	15 %	26
6	Cutting coil leg#1	664	24	15 %	28
7	Cutting coil leg#2	235	8	15 %	9
8	Dispenser	1,524	54	15 %	63
9	Inductance test	204	7	15 %	8
10	Leakage test	206	7	15 %	8
11	Stamping	234	8	15 %	9
12	Visual inspection	797	29	15 %	35
	Total				299

Table 6 represents the results of normal time and the standard time for all production processes calculated after the improvement in the experiment. In addition, results comparing time before and after improvement are depicted with the bar graph and cumulative time with the line graph in Figure5

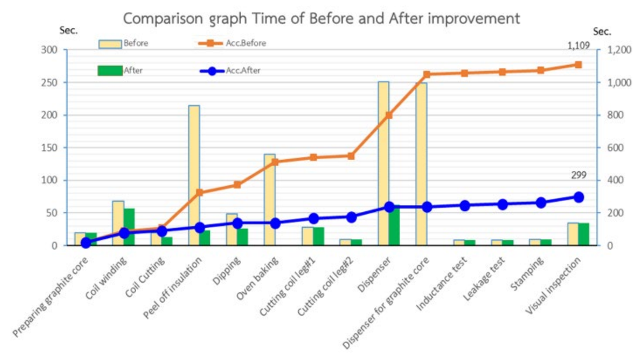


Figure 5 Results Comparing Time Before and After Improvement

A Lean approach showed better efficiency in the elimination of wastes and non - value added works for the improvement processes of electronic manufacturing industry. Reducing waste and manufacturing cost, and increasing production capability are the target goals making profits and stability for businesses. It is important that business with capital human labor needs to increase their workers' work efficiency.

Study of workers' excessive movement in the assembly line will benefit managing engineer in assessing and planning for improvement by removing them, so that the fatigue of operating workers will be reduced. Therefore, time measurement using MTMs technique is an easy and convenient mean helping track the movement and study of time for assembly line's operators. However, MTM2 may cause problem of nervousness and tense of workers during work operation and result in uncomfortable movement. Explanation and understanding on reasons of workers' operation observation are important.

4.0 CONCLUSION

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Acknowledgement

This paper was developed with the data support from Mr.Theerapong Thongphun who is a manager of transformer production department of the case study firm. The authors thank Associate Professor Apichat Sopadang for his helpful discussions and theories in Lean concept.

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