ASPHALT PAVING PRODUCTIVITY IMPROVEMENT: A CASE STUDY OF SLS COMPANY IN THAILAND

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ABSTRACT

This study is a case of a road construction company in Thailand. The company was facing a higher lead time for laying asphalt. The total amount of production of laying asphalt from July 2022 to April 2023. The standard time is 206.84 hours, while the actual time is 573 hours, resulting in an extra 366.16. This research aimed to identify problems, find solutions, and implement appropriate measures to improve the production time of laying asphalt. Recommendations, solutions, and preventive actions were provided to improve the production time of laying asphalt and prevent recurrent problems. This research applied the DMAIC concept to define the problems, measure the actual performance, analyze the root causes of the problem by applying the Fishbone diagram and Pareto chart, and identify the improvement of the current process. The main root causes of this issue were machines, the environment, and people. The result after implementing the improvement plan was successful. Since the implementation started, the asphalt laying production time has gradually decreased. In comparison to the actual time with the standard time, indicating a satisfactory outcome as the actual time is lower than the standard time. The DMAIC concept can improve the production time for laying asphalt. As a result, the DMAIC is an effective tool to improve the company's production process.

Key words: *Supply chain management, DMAIC, Fishbone diagram, Pareto chart, Brainstorming*

บทคัดย่อ

งานวิจัยนี้ เป็นกรณีศึกษาของบริษัทก่อสร้างถนนแห่งหนึ่งในประเทศไทย บริษัทกำลังเผชิญกับระยะเวลาการผลิตที่สูงขึ้นในการปูยางแอสฟัลต์คอนกรีต จำนวนการปูยางแอสฟัลต์คอนกรีตทั้งหมด ตั้งแต่ กรกฎาคม พ.ศ. 2565 ถึง เมษายน พ.ศ. 2566 เวลามาตรฐาน 206.84 ชั่วโมง เวลาที่ใช้ในการปูยางแอสฟัลต์คอนกรีต 573 ชั่วโมง ส่งผลให้เวลาเกินไป 366.16 ชั่วโมง งานวิจัยนี้มีวัตถุประสงค์เพื่อระบุปัญหา ค้นหาแนวทางแก้ไข และดำเนินมาตรการที่เหมาะสมเพื่อปรับปรุงเวลาในการปูแอสฟัลต์คอนกรีต มีข้อเสนอแนะ แนวทางแก้ไข และมาตรการป้องกันเพื่อปรับปรุงเวลาในการปูยางแอสฟัลต์คอนกรีตและป้องกันปัญหาซ้ำ งานวิจัยนี้ใช้แนวคิด DMAIC เพื่อกำหนดปัญหา วัดประสิทธิภาพจริง วิเคราะห์ต้นตอของปัญหาโดยใช้แผนภูมิก้างปลา และแผนภูมิพาเรโต รวมถึงการปรับปรุงกระบวนการในปัจจุบัน สาเหตุหลักของปัญหานี้ คือ เครื่องจักร สิ่งแวดล้อม และคน ซึ่งประสบผลสำเร็จด้วยดีหลังจากดำเนินการตามแผนปรับปรุง นับตั้งแต่เริ่มดำเนินการระยะเวลาในการปูยางแอสฟัลต์ก็ค่อย ๆ

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ลดลง เมื่อเปรียบเทียบเวลาจริงกับเวลามาตรฐาน แสดงให้เห็นผลที่น่าพอใจ เนื่องจากเวลาจริงต่ำกว่าเวลามาตรฐาน แนวคิด DMAIC สามารถปรับปรุงเวลาการผลิตสำหรับการปูยางแอสฟัลต์ได้ ด้วยเหตุนี้ DMAIC จึงเป็นเครื่องมือที่มีประสิทธิภาพในการปรับปรุงกระบวนการผลิตของบริษัท

คำสำคัญ: โซ่อุปทาน DMAIC แผนภูมิก้างปลา แผนภูมิพาเรโต การระดมความคิด

INTRODUCTION

Asphalt roads and concrete roads are the two most common forms of road construction. Asphalt roads provide a durable and smooth surface for automobiles. They can handle a lot of traffic and are easy to build or fix quickly. Concrete roads are suitable for heavy traffic and industrial areas due to their high strength and durability. They are more durable than asphalt roads but are more expensive to build and take longer to cure.

The asphalt road is the main product of the company, so the company needs to focus on production time. The company must serve the product in good quality within the specification standard to the customer. Moreover, the production time is very important for the company. If the production team uses more time for production, it means that the company must bear the higher labor costs. Furthermore, the cost of the machine's fuel will increase if it takes longer to produce a product, requiring more materials to complete the same quantity of work.

In this case, the company might pay the higher cost of overtime for the production team and fuel costs. Therefore, they need to find out the reason why it occurred. If the company can solve the problem, it can create benefits for the company, such as reducing overtime and fuel costs. As a result, the company can save costs, and the production team has more time to relax.

The purpose of this research was to improve the laying of asphalt at one of the road construction companies. The following were the objectives of this research. The company would like to identify the root causes of delay problem in the production process. They apply the DMAIC model to improve the production process of the SLS Company. They implement plans for improving and minimizing the production process. They would like to reduce the overtime payment of SLS Company.

The production process of laying asphalt per 500 square meters should not be more than 35 minutes after the truck arrives at site work. The current transactions on average take around 156.01 minutes, of which the standard is 35 minutes. The average production time for those 10 months is 156.01 minutes. Currently, there is a great deal of competition in the market for road construction, which has a direct impact on the company's profit as its market share decreases. In addition, SLS Company has issues with asphalt laying taking longer than expected. The main research question is "**How to improve the production time of laying asphalt?**" Through this research, the researcher would like to find the appropriate method to improve the root causes of delay problem in the production process.

LITERATURE REVIEW

This chapter presents a discussion of the selected literature review that relates to the research on how to enhance the production time of laying asphalt. The theories, tools, methodologies, and techniques chosen to be described in this chapter assist in identifying the root causes of asphalt laying delays and determining how to enhance asphalt laying production times. In the following section, the DMAIC model, process map, Pareto diagrams, and Fishbone diagram are discussed.

DMAIC (Define-Measure-Analyze-Improve-Control)

The DMAIC (Define, Measure, Analyze, Improve, and Control) technique of Six Sigma can be viewed as a road map for issue resolution and the improvement of products and processes (Krishnan & Prasath, 2013). Sokovic, Pavletic, and Pipan (2010) stated that the DMAIC methodology is a data-driven life-cycle approach to Six Sigma initiatives for the purpose of process improvement. The explanations for each stage are in their most concise form. During the Define phase, the proper project is found, its priorities are established, and it is selected. The Measure phase is necessary in order to determine the variety of process parameters and their performances. During the Analyze phase, important reasons and factors that affect the process are identified. During the Improve phase, changes are made to the process and its effectiveness is improved. In the Control phase, the gain is kept at a steady amount.

Process Mapping

In the early 1900s, Frank Gilbreth was the first person to introduce the concept of process mapping. It is effective in a wide variety of situations and levels of detail. Creating a process map is essential. It assumes no predetermined set of arrangements, tools, or method (Lee & Snyder, 2023). McCreight et al. (2019) mentioned that process mapping is a tool used in the Lean Six Sigma process improvement method. This method started in the manufacturing industry but is now used more and more in service organizations like healthcare to improve existing processes. To map a process, steps must be observed, responsibilities must be determined, and inputs and outputs must be specified.

Pareto Diagram

Shankar (2009) stated that the 80/20 formula defined by Vilfredo Pareto forms the basis for the Pareto diagram. Pareto analysis is a quality control tool that ranks data in order of how often it happens, from most to least (Fotopoulos, Kafetzopoulos, & Gotzamani, 2011). The total frequency is equal to 100% (Fotopoulos et al., 2011). This rule states axiomatically that 20% of activities will cause 80% of defects in a given situation (Shankar, 2009). The Pareto chart assists us in determining the most common root cause so that we can easily focus on that specific root cause and find a possible solution to counter it (Awaj, Singh, & Amedie, 2013). Sahoo (2014) stated that the Pareto chart is depicted as a scale in a picture of a histogram in a vertical bar graph. The root causes are then graphically displayed and easily understood by directing attention to the correct problem.

Fishbone Diagram

The Fishbone diagram, also known as a cause-and-effect diagram for root cause analysis, and the idea of quality control (QC) circles are believed to have originated with Kaoru Ishikawa, who is regarded by many researchers as being their primary proponent. It is also known as the Ishikawa

diagram or the Fishbone diagram because the shape of the diagram resembles the skeleton of a fish. It is used to determine the level of significance of quality issues based on the severity of the issues (Neyestani, 2017). Moreover, the Fishbone diagram is a graphical technique that is useful for locating and significantly analyzing the factors that influence the characteristics of work output quality (Slameto, 2016). The root-cause analysis, as well as the product design, are two of the many applications of the fishbone diagram that can be found in the activities of quality improvement and process management. Bose (2012) also mentions that the Fishbone diagram is split into six sections, which are the main causes of any business process problems. It has a method, material, measurement, people, an environment, and a machine.

ANALYSIS AND FINDINGS

This chapter describes the tools and methods that were used to identify and eliminate the root causes of the delayed laying of asphalt in this case study. This analysis was based on the total production that happened for the 10-month period from July 2022 to April 2023. DMAIC was used to solve this problem in five steps. This analysis followed DMAIC: Define, Measure, Analyze, Improve, and Control. For the Define phase, a bar chart, a project charter, and SIPOC were used to identify the problem. To measure the current state, collection and process mapping were applied in the Measure phase. In the Analyze phase, a Fishbone diagram, a bar chart, and a Pareto chart were used to identify root causes. For the Improve phase, brainstorming concepts to find the new process were applied. Additionally, KPI was applied in the Control phase.

Table 1 demonstrates the steps of the DMAIC process including the effective tools that were used in this study.

Table 1: Steps of the DMAIC Process

Phase	Methodology	Tools
Define	- Identify the problem - Create a project charter	Bar chart, Project charter, SIPOC
Measure	- Plan for collecting the data	Data collection, Process map
Analyze	- Apply a Fishbone diagram to identify the root cause	Fishbone, Bar chart, Pareto chart
Improve	- Apply the brainstorming concept to find a new process and implement the plan	Brainstorm
Control	- Monitor and control for sustained improvement	KPI

Define Phase

In the Define phase, the researcher collected data from the production team to see the performance of laying asphalt for SLS Company that happened from July 2022 to April 2023. The data that the company had focused on the delayed production time of laying asphalt, Figure 1 shows the average production time for each month from July 2022 to April 2023. The overtime pay for the production team is 660 Baht per hour. Additionally, the total cost of overtime during those 10 months that the

company paid was around 98,340 Baht. As a consequence, the ratio of overtime pay to total revenue is 0.16 percent.

Figure 1: Average of Production Time

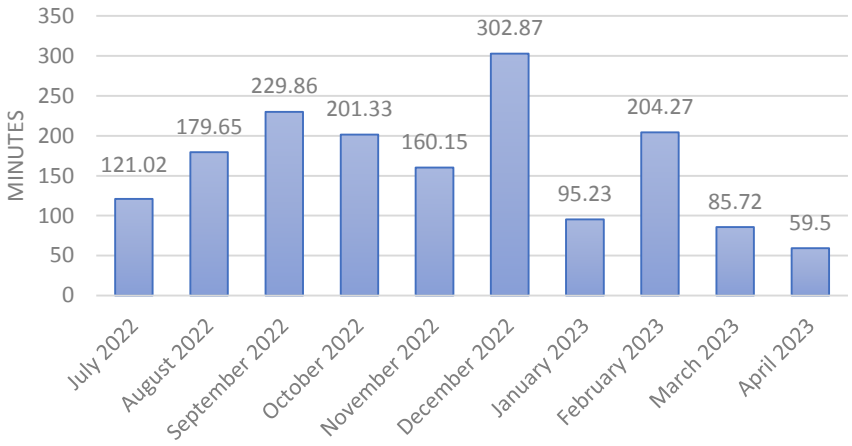


Table 2 shows the project charter, which was created to ensure that everyone in the team understands the process. Moreover, the project charter shows the overview in terms of project name, business case, problem statement, goal statement, benefits to internal and external customers, project scope, project milestones, and team members. The business case is to decrease production time and overtime payments.

Table 2: Project Charter

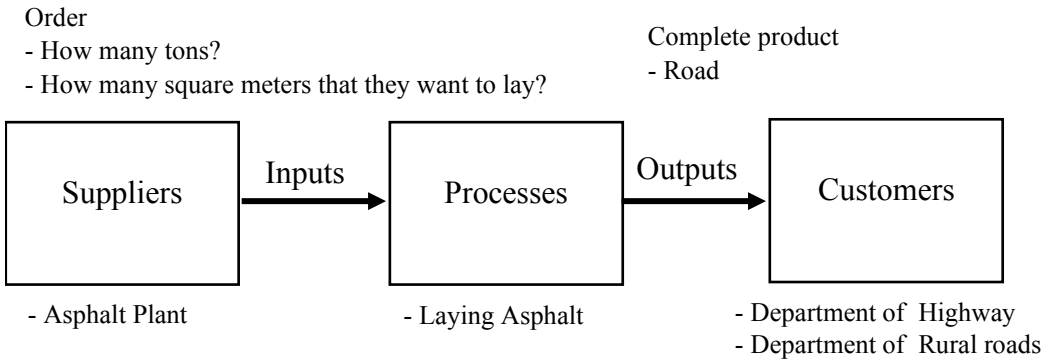
Project name	DMAIC to improve the production time for laying asphalt
Business Case	To decrease production time and overtime payments
Problem Statement	The production process of laying asphalt per 500 square meters should not be more than 35 minutes after the truck arrives at site work. The current transactions, on average, take around 156.01 minutes, whereas the standard is 35 minutes. From July 2022 to April 2023, the company paid for overtime of around 98,340 Baht. Therefore, the ratio of overtime pay to total revenue is 0.16 percent, which is beyond the criteria of the company and needs to be modified.
Goal Statement	Ninety percent (90%) of laying asphalt per 500 square meters should not take more than 35 minutes. Moreover, it is favorable for the company to reduce the overtime payment of the production team to not more than 0.12 percent per month compared with revenue.
Benefits to Internal and External Customer	1. The company pays less for overtime. 2. The company can collect revenue from the customer more quickly. 3. The workers can rest longer time after completing their work.

Table 2: Project Charter (Cont.)

Project Scope	The project is focused on contacting the supplier to place an order for hot mix, laying asphalt at the construction site, and interacting with the government department.
Project Milestone	Define during 1st week of May Measure during 2nd week of May Analyze during 3rd week of May Improve from May to July Control from June to July
Team Members	Production team

Figure 2 presents the SIPOC of SLS Company. For the supplier, the company orders its hot mix asphalt from a factory in the same province, allowing greater control over the product's quality. For the input, they will get the client's order, specifying how many square meters of the road they wish to construct. For the process, there are five steps in the production procedure. For the output, the finished product of our company is an asphalt road that is ready for use. For the customers, they often interact with the Department of Highway and the Department of Rural Road.

Figure 2: SIPOC



Measure Phase

In the Measure phase, the researcher obtained the data from the production department. In this case, when the production team works more than the standard time, the production department has to report to the owner of the company as well as update the working schedule every day.

The data has been selected only for the asphalt product, which includes the number of square meters, standard time, actual time, and extra time. Table 3 shows the number of square meters of road construction, standard time, actual time, and extra time from July 2022 to April 2023. Total road construction for 10 months is 177,295.60 square meters. The standard time should be 206.84 hours, but the actual time of previous construction is 573 hours. As a result, the production team has used 366.16 hours for the extra time spent constructing the road.

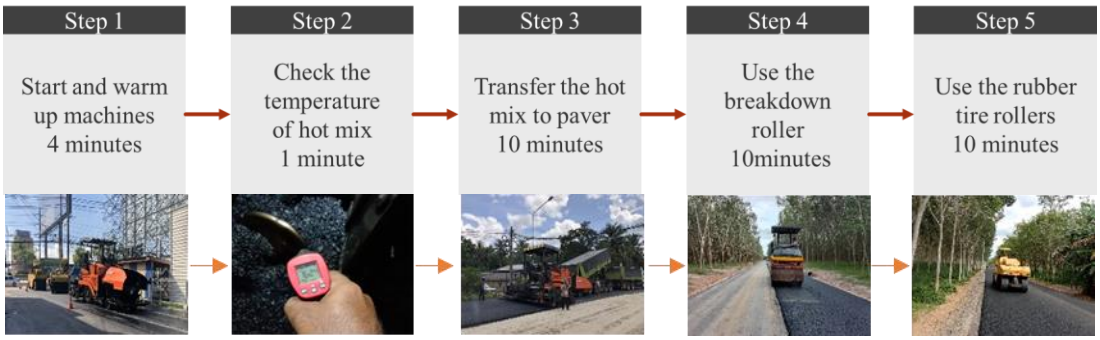
Figure 3 shows the detailed process map for laying asphalt. There are five steps to laying asphalt. First, the worker at the construction site starts and warms up the machine for four minutes before

Table 3: Report of Road Construction from July 2022 to April 2023

Month-Year	Sq m	Standard Time	Acutal Time	Extra time
Jul 2022	26,165.11	30.53	100.50	69.97
Aug 2022	2,862.15	3.34	17.00	13.66
Sep 2022	9,968.79	11.63	51.50	39.87
Oct 2022	5,774.83	6.74	31.00	24.26
Nov 2022	3,360.86	3.92	17.00	13.08
Dec 2022	10,046.70	11.72	73.00	61.28
Jan 2023	23,403.04	27.30	66.00	38.70
Feb 2023	17,426.39	20.33	47.00	26.67
Mar 2023	51,317.93	59.87	119.00	59.13
Apr 2023	26,969.79	31.46	51.00	19.54
Total	177,295.60	206.84	573.00	366.16

utilizing it. Second, the worker checks the temperature of the hot mix one minute after the truck has arrived at the construction site. Third, the worker lays the hot mix on the paver to manage the road's thickness, which takes 10 minutes. Fourth, the worker immediately follows the hot mix pass from the paver by using the breakdown roller to lower the temperature of the hot mix and to make the surface of the road smooth for 10 minutes. Last, the worker uses the rubber tire rollers for 10 minutes to increase the density of the road.

Figure 3: Detailed Process Map for Laying Asphalt



Analyze Phase

The objective of the Analyze phase is to identify the root cause of the delayed laying of asphalt. For this phase, the researcher applied the Fishbone diagram and Pareto chart to analyze the root cause.

The secondary data that the researcher used came from the production department, a civil engineer, as well as interviews with the owner of SLS Company. As a result, the researcher was able to know the cause of the problem and how to address it. According to Figure 4, several problems affect the delayed laying of asphalt.

Figure 4: Fishbone Diagram

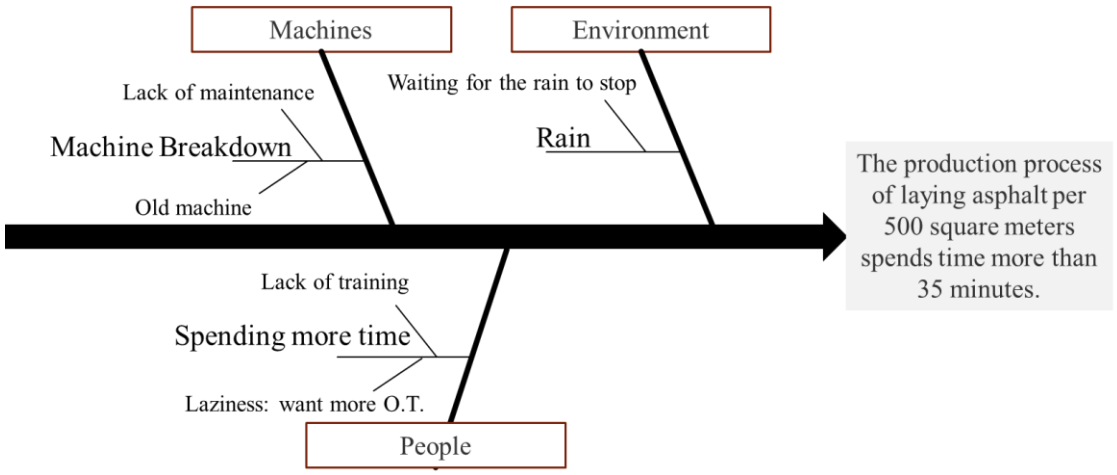


Figure 5 shows that there are three main reasons for the delay: a broken machine, rain, and people. The total delay is 98 times. The machine breaks down 58 times, which is 59.18 percent. Rain happens 37 times, which is 37.76 percent. Last, the delay from people is three times, which is 3.06 percent.

Figure 5: Main Causes of Delay

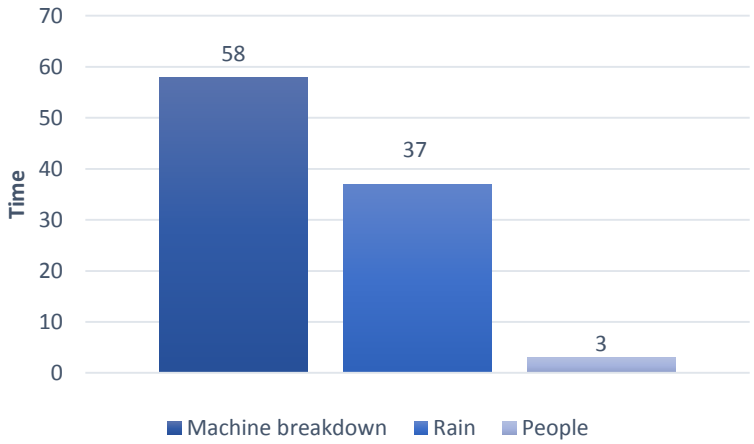
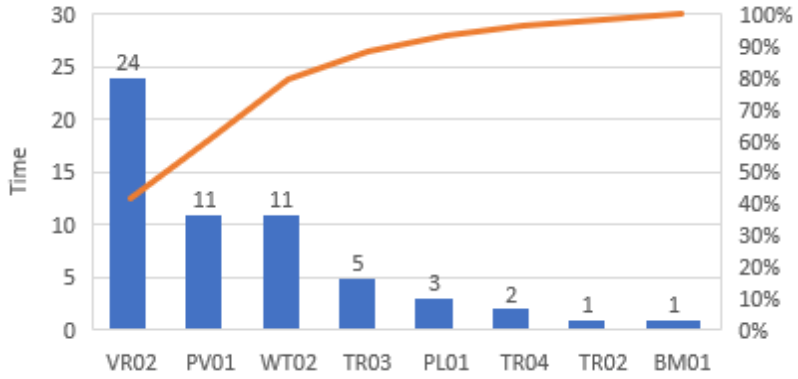


Figure 6 demonstrates the causes of machine breakdown. The total number of machine breakdowns is 58, caused by VR02, PV01, WT02, TR03, PL01, TR04, TR03, and BM01. There are three machines that cover 80 percent of the total machine breakdowns. VR02, PV01, and WT02 are the three machines that frequently break down. These three machines have a total maintenance cost of 241,775.83 Baht, which has a significant impact on SLS Company's expenses.

At the end of the Analyze phase, the root causes that SLS Company should consider improving are the machine, Environment, and people. For the machine, machine breakdown is the main reason for longer production times caused by VR02, PV01, and WT02, as these tasks require

intense concentration. The rainfall is the main factor contributing to longer production times in nature. Lastly, unskilled labor is the most important aspect of SLS Company that must be enhanced. These factors should be considered during the Improve and Control phases.

Figure 6: Machine Breakdown Causes



Improve Phase

The improvement plan developed the most effective method and strategy for eliminating the root causes identified in the Analyze phase. According to the Analyze phase, the researcher has found that the root causes of the SLS Company problem are machines, the environment, and people. To solve these root causes, the improvement action plan was implemented based on three main factors: too-old machines, weather conditions, and people's lack of skill. Table 4 demonstrates the improvement plan for the root causes for the relevant person.

Table 4: Improvement Plan of Root Causes

Root Cause	Improvement plan	Relevant person
Too-old machines	- Reviewing the maintenance process - Checking the machine - Using the spare part same brand as the machine - Investing in a new machine which is a breakdown roller. - Standing by for maintenance	- Production team - Purchasing department - Maintenance department - Owner of Company
Weather Condition	- Checking the weather before ordering the hot mix - Creating a new rule during the rainy season	- Production team - Civil engineer - Owner of Company
People to be Lack of Skill	- Training course for new worker - Creating a clear report - Controlling of laying asphalt on each dump truck	- Production team - Civil engineer - Owner of Company

The report on road construction before and after implementation is displayed in Table 5. The total production of road construction before implementation is 177,295.60 square meters. The difference between the standard time of 206.84 hours and the actual time of 573 hours is 366.16

hours. After implementation, SLS's total production is 15,660.30 square meters. Compared to the actual time of 18.22 hours, the standard time is 18.27 hours. As a result, this method is successful after implementation because the actual time is less than the standard time.

Table 5: Report of Road Construction Before and After Implementation

Before Implemented				
Month-Year	Sq m	Standard Time	Acutal Time	Extra time
Jul 2022	26,165.11	30.53	100.50	69.97
Aug 2022	2,862.15	3.34	17.00	13.66
Sep 2022	9,968.79	11.63	51.50	39.87
Oct 2022	5,774.83	6.74	31.00	24.26
Nov 2022	3,360.86	3.92	17.00	13.08
Dec 2022	10,046.70	11.72	73.00	61.28
Jan 2023	23,403.04	27.30	66.00	38.70
Feb 2023	17,426.39	20.33	47.00	26.67
Mar 2023	51,317.93	59.87	119.00	59.13
Apr 2023	26,969.79	31.46	51.00	19.54
Total	177,295.60	206.84	573.00	366.16
After Implemented				
Month-Year	Sq m	Standard Time	Acutal Time	Extra time
May 2023	11,954.60	13.95	13.92	0.00
Jun 2023	3,705.70	4.32	4.30	0.00
Total	15,660.30	18.27	18.22	0.00

Consequently, the SLS company has completed the implementation. In Table 6, the before and after overtime pay of SLS Company is presented. The ratio of SLS Company's overtime payment to total revenue has decreased, which is less than the company's goal (the goal is to not exceed 0.12% of the total revenue each month). In addition, in May 2023 and June 2023, overtime pay as a percentage of total revenue is 0.11 percent and 0.10 percent, respectively.

Comparing data from July 2022 to April 2023, the overtime payment fluctuated, and the company has no control over the overtime pay percentage. The result of implementation is demonstrated by the fact that the percentage of overtime pay to total revenue for the most recent two months has decreased after implementation. According to the implementation's beneficial results for the company, the company can save more money on overtime pay, increasing its revenue.

Control Phase

In this phase, the emphasis is on continuous process and operation improvement, as well as controlling the long-term sustainability plan. To prevent the problem in the long term, the company should evaluate its performance and maintain it in accordance with improvement criteria. In addition, it is necessary to monitor the SLS Company's asphalt laying improvements in terms of production time reduction. The team must work in accordance with the standard operating procedure and achieve the KPI.

Table 6: Overtime Pay to Total Revenue Before and After Implementation

Before Implementation				
Month-Year	REV (฿)	O.T. (฿)	O.T. pay/Total REV	O.T. pay/Total REV Average
Jul 2022	9,157,789.59	24,090.00	0.26%	0.16%
Aug 2022	1,001,754.14	660.00	0.07%	
Sep 2022	3,489,077.98	7,590.00	0.22%	
Oct 2022	2,021,190.78	4,620.00	0.23%	
Nov 2022	1,176,299.29	660.00	0.06%	
Dec 2022	3,516,343.73	11,220.00	0.32%	
Jan 2023	8,191,062.26	11,880.00	0.15%	
Feb 2023	6,099,237.66	4,620.00	0.08%	
Mar 2023	17,961,275.95	25,740.00	0.14%	
Apr 2023	9,439,426.89	7,260.00	0.08%	
After (goal no more than 0.12% per total revenue)				
Month-Year	REV (฿)	O.T. (฿)	O.T. pay/Total REV	O.T. pay/Total REV Average
May 2023	4,184,273.12	4,620.00	0.11%	0.11%
Jun 2023	1,296,995.16	1,320.00	0.10%	

Key Performance Indicator (KPI)

In the Control phase, the researcher and teams utilized the key performance indicator to monitor the company's performance by controlling the system. The KPI is also used to evaluate past performance to determine whether the company will be able to reach its objective after implementing the enhancement. It can help the company sustain its operations, determine which areas require improvement, and prevent the recurrence of problems. The KPI is to reduce the ratio of overtime pay to total revenue as well as production time so that the company can sustain the improvement over time.

Standard Operating Procedure (SOP)

In addition, once the implementation has been completed, the standard operating procedure must be revised. SOP establishes guidelines for activities such as reviewing the maintenance process, checking the machine, standing by for maintenance, checking the weather before ordering the hot mix, creating a new rule during the rainy season, creating a clear report, and controlling the laying of asphalt on each dump truck. It helps the company to be consistent, achieve the same objective, and standardize asphalt laying. As standard operating procedure makes daily operations more predictable, the implementation of this strategy ensures that their responsibilities will be performed effectively while also reducing errors and increasing productivity. It is beneficial for all members of the production team to understand the company's new processes and regulations.

Weekly Team Meeting

After the implementation has been completed, the weekly meeting needs to be held. Every Monday, the company holds a weekly meeting and submits the production report of the production team to the SLS office. The meeting provides an opportunity to analyze the roots that caused the problem, in addition to monitoring the performance of laying asphalt. The owner of SLS Company, a civil engineer, and members of the production team are in attendance at the weekly meeting. This

meeting is held every week to ensure that the issue that occurred during the previous week will be brought up in the meeting and steps will be taken to resolve the issue immediately.

Long-term Training Programs

Long-term training programs should be planned and implemented to maintain and improve the employee's skills. As road construction is a niche production, the company must provide a cross-training section for the production team, such as how to drive or control the machine and equipment. Knowledge of how to operate the machines and equipment utilized for road construction, including the paver, breakdown roller, rubber tire roller, asphalt lute rake, and shovel, will benefit the company when there is a shortage of skilled labor, allowing the work to continue.

CONCLUSION AND RECOMMENDATIONS

The DMAIC model is a guide that explains how to solve a problem efficiently and effectively. It can assist the company in achieving its key performance indicators of reducing the ratio of overtime pay to total revenue and reducing production time. Applying the DMAIC model to improve production time, this research aims to identify the causes of asphalt laying delays. In addition, it also helps the team understand the root causes of the problems as well as use the potential tools to create a possible solution to solve the problem. Moreover, the implementation plan and new improvements have been developed in areas that need improvement. Therefore, this research might assist the company in reducing asphalt laying production time and cost in the long term. Lastly, the essential phase is the Control phase, which has also been implemented to ensure the sustainable production of laying asphalt with good performance.

There are limitations to this study. First, the researcher concentrated solely on SLS Company due to the availability of data and time constraints. Secondly, the researcher used historical data from July 2022 to April 2023 to determine the root causes of the problem. Furthermore, the researcher analyzed the main causes of asphalt laying but did not cover all areas of the production process in the company. So, the main topic analyzed in this research was only the laying of asphalt. According to the Fishbone diagram in the method category, asphalt thickness varies based on the contract's specifications. For this study, the researcher concentrated solely on pavement thicknesses of 5 centimeters, excluding all other asphalt production thicknesses. Lastly, due to time constraints, the research concluded with the implementation of an enhancement plan with the team from May to June 2023, followed by a summary of the results around July 2023, for only three months, which is a short period.

According to the study, the DMAIC model should be applied to the delayed laying of asphalt for road construction in Thailand. It is strongly suggested that this study serve as a guide and be applied to other businesses confronting similar issues as SLS Company. In addition, the company can use the DMAIC model to implement and address problems in other business areas, not just the delayed asphalt laying issue.

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