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Enhancing Warehouse Management Efficiency for Precast Concrete Product Business

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ABSTRACT

Nowadays, technology plays a significant role in businesses, whether small or large. Companies leverage technology to gain a competitive edge in the business world and to adapt the era of information technology. This research aims to enhance warehouse management efficiency, using precast concrete product manufacturing as a case study. The company intends to implement a web-based application to enhance warehouse management efficiency. The decision is prompted by issues encountered in the case study where the quantity of products in the system does not match the actual quantity in the warehouse or stock diff, and the cost of warehouse management is high. This led to the proposition of applying the Lean concept. The Lean concept has been utilized through the use of the Value Stream Mapping (VSM) tool to analyze the workflow and categorize activities in the process using the 8 wastes. The analysis revealed that non-value activities include checking stock, document issuing, and managing transport schedules. Subsequently, improvement directions were identified to reduce waste following the principles of ECRS. The next step involved designing and developing a web-based application prototype tailored to the specific operational needs. From testing and evaluation, it was found that the inventory accuracy rate increased. Before implementing the web-based application, the average percentage of stock diff was 107.54%. After experimenting with the web application in process, the average percentage of stock diff decreased to 18.48% and the cost of the warehouse per sale, measured by the salary or wages of warehouse staff, decreased from 60,500 baht per year to 44,000 baht per year.

Keywords: Concrete factory; Efficiency improvement; Value stream mapping

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1. Introduction

Ready-mixed concrete is widely used in construction projects of various types and sizes, including residential homes, office buildings, hotels, schools, etc., both in the public and private sectors. Due to the ease of quality control, safety, and versatility, ready-mixed concrete proves to be advantageous in various construction projects. It contributes to the reduction of construction time and allows for effective cost management. Therefore, the development of efficient processes and good project management can enhance competitiveness in the business.

This study aims to enhance the efficiency of inventory management by applying Lean Production principles, with a focus on analyzing strategies for enhancing efficiency in the inventory management system by using value stream management tools and applying the ECRS principles as guidelines for process enhancement. Then a prototype web-based application will be designed and developed to suit the use and put it to trial to evaluate both costs and inventory accuracy rates.

In this study, the researcher utilized data from a precast concrete manufacturing and distribution company to conduct the research. Due to the case study company's lack of accurate inventory data, disparities between system-recorded and actual on-site inventory were identified. Consequently, the company expressed the need to implement a web-based application to improve the efficiency of inventory management. In addition, the researcher has studied and collected data on the operational activities of the case study company, ranging from customer product orders to the delivery or shipment of products to customers.

2. Literature Review

2.1 Lean manufacturing

Lean Manufacturing is a methodology for developing production processes with a focus on efficiency such as cost reduction, shortened production timelines, responsiveness to market demands, and improvements in the quality of services or products. Lean consists of 5 core components, namely:

1. Value: Identifying activities that add value and create customer satisfaction. Any activity that does not add value is considered waste and should be reduced or eliminated.
2. Waste Reduction Principle: Reducing costs and time by identifying and minimizing waste in the production process, such as waiting, transportation, and non-value-added processing.
3. Flow: Creating processes that are smooth and continuous without interruptions, allowing them to adapt to customer demand.
4. Pull A production system that responds to customer demand, avoiding overproduction or creating products without orders.
5. Continuous Improvement: Setting goals for ongoing development and improvement of processes, emphasizing learning from experiences, and encouraging everyone to participate in continuous improvement processes.

In Paker [1] research, Lean Thinking principles from Womack and Jones [2] book and the Toyota Production System (TPS) were employed to analyze the entire process flow in a company related to the automotive industry. The goal was to improve the product development process. The research found that Lean Thinking and TPS concepts effectively and sustainably contribute to enhancing the overall process flow of the automotive industry. In this research, the fundamental components of Lean Manufacturing principles were applied, including the utilization of tools, and supporting factors associated with Lean concepts in certain processes for study purposes.

2.2 8 Wastes

The utilization of any resources without creating added value or making the

product or service more valuable is something that does not contribute value to the customer or doesn't result in any change. In Japanese, it is called "Muda" and can be divided into 8 types, known as DOWNTIME:

1. Defects: Flaws or imperfections in the product or service.
2. Overproduction: Producing more than what is required by the customer.
3. Waiting: Unnecessary waiting time during processes.
4. Non-utilized Talent: Not utilizing the full potential of resources and abilities.
5. Transportation: Unnecessary movement or transportation of materials or products.
6. Inventory Excess: Holding more inventory than necessary.
7. Motion Waste: Unnecessary or inefficient movement that does not add value.
8. Excessive Processing: Performing unnecessary work that adds complexity to the process.

The research conducted by Kavanagh et al. [3] applies the principles of the 8 wastes in the communication process between employees and customers to reduce resource wastage and enhance efficiency in operations. The analysis focused on the communication processes within a company in Bloomington, Illinois. It identified that the 8 types of waste could be pinpointed and addressed in specific steps or activities, leading to a reduction in waste. This helped the company reduce costs and improve operational efficiency.

2.3 Value stream mapping

Value Stream Mapping is a tool used to illustrate the sequence of steps in a process by visually representing various activities. It aims to provide an overview of different activities that occur, aiding in identifying areas for process improvement and enhancing resource utilization throughout. It is important for companies to identify problems or areas that need improvement. This can involve interviewing management and studying current work processes that are identified as problematic or in need of improvement. To gain a comprehensive understanding of the issues, observing activities related to the process that require improvement may be necessary, to record the steps and documents spent on each activity. This can help to pinpoint where improvements can be made and how to best address the problems at hand. Categories are as follows:

1. Value-Added Activities (VA): These are operations that provide value in the workflow. They are necessary and aim to physically change materials or information to meet specific requirements.
2. Non-Value-Added Activities (NVA): These are activities that consume resources, such as time, labor, or space, without contributing to customer satisfaction.
3. Necessary but Non-Value-Added Activities (NNVA): These are activities that may result in waste but are deemed necessary and are accepted. Examples include material handling, scheduling, and communication for information dissemination.

The book by Rother et al. [4] explains the use of Value Stream Mapping (VSM) techniques to increase value and reduce waste (MUDA). It outlines methods to identify Value-Added Activities (VA) and Non-Value-Added Activities (NVA) in business processes. Similarly, the research conducted by Bonfante et al. [5] applies the concept of Value Stream Mapping (VSM) to small businesses, introducing sustainability or Sus-VSM.

For Value Stream Mapping (Sus-VSM), the research findings indicate that it can effectively reduce waste in business and improve activities sustainably, while being environmentally friendly.

2.4 ECRS

The principle of reducing waste with ECRS is a concept aimed at simplifying and improving efficiency in

various processes or activities within a business or organization. It focuses on eliminating non-value-added activities and managing those activities to be as efficient as possible. It consists of:

1. Eliminate: Activities that do not add value or are unnecessary will be eliminated to reduce complexity and increase efficiency.
2. Combine: Similar or compatible activities may be combined to reduce redundancy.
3. Replace: Introducing new technologies or methods to replace inefficient activities.
4. Simplify: Making processes or activities straightforward and less complex.

This principle aims to ensure that all activities in the process are valuable and highly efficient to create value for customers and the organization. In addition, the ECRS principle is often combined with Value Stream Mapping (VSM) to provide a comprehensive view of the process and enable efficient problem-solving or improvement. For example, a study conducted by Hu et al. [6] utilized ECRS techniques to enhance the efficiency of the tool cleaning process. The researchers analyzed the process by creating current-state and future-state Value Stream Mapping (VSM) after implementing ECRS techniques for process improvement. The results showed a reduction in the number of steps in the process from 14 to 13 and a 2.11% decrease in the cleaning time per piece.

2.5 Web-based application

It refers to computer programs or applications that are developed and operate on a web browser without the need for installation on the user's computer. Users can access and use these programs through the internet using a web browser. In a research study by Maheshwari et al. [7] digital twin technology was introduced for warehouse management. The focus was on managing warehouse systems by creating a Virtual Model to visualize the overall operations or systems of the warehouse through a web-based application and the Internet of Things. As with the research conducted by Rejeb et al. [8] the utilization of the Internet of Things (IoT) in the Halal Supply Chain system aims to enhance efficiency and accuracy in warehouse management. The system is designed to enable real-time monitoring of products in the warehouse. The research findings indicate that the warehouse management system is significantly more efficient and accurate because of these improvements.

The previous research indicates that a web application can address issues and enhance efficiency in warehouse management. In this study, we aim to use a web application to improve the efficiency of warehouse management customized to the specific requirements and processes of the case study company. We will follow the Software Development Lifecycle as a practical guideline for small-scale software development to analyze and design the web application. Here are the details of the plan.

1) Analysis: To identify areas of improvement, the analysis begins with data gathering, followed by the creation of a current Value Stream Mapping. This illustrates the entire workflow and identifies activities that contribute to waste. Next, the 8 Wastes concept is applied to categorize and specify details of the waste. After this, the ECRS principle is employed for improvement, ultimately leading to the development of a future Value Stream Mapping.

2) Design: To align the software with the requirements identified in the previous steps, this research will utilize the MySQL database along with the PHP (PHP Hypertext Preprocessor) programming language to create the web application. MySQL serves as the database management system, designed, and adapted for compatibility with web applications, capable of working seamlessly with any platform. As for PHP, it is a computer

programming language suitable for internet-based applications, making it well-suited for web application development.
3) Implementation: Testing the designed web application and evaluating its functionality, assessing its suitability for use. In this research, the evaluation will be based on the Inventory Accuracy Rate.

3. Methodology

3.1 Identify the company's problems and needs.

It's important to identify the issues within a company and determine areas for improvement. This can involve interviewing management and studying current work processes to pinpoint areas that are problematic or in need of improvement. By observing activities related to the process that require improvement while recording the steps and documenting the time spent on each activity, it's possible to gain a comprehensive understanding of the overall problems.

3.2 Study of value stream management

The steps involve applying the theory of Value Stream Management to analyze the recorded process by categorizing activities into three types: 1. Value-Added (VA), 2. Non-Value-Added (NVA), and 3. Non-Necessary Value-Added (NNVA). Subsequently, creating a Value Stream Mapping to illustrate the overall process by depicting the current Value Stream Mapping. Then, analyze the types of waste that occur in activities based on the concept of the 8 Wastes or DOWNTIME.

3.3 Identifying strategies for waste reduction

Specify guidelines for reducing waste using the principles of ECRS. Analyze activities categorized as NVA (Non-Value-Added) and NNVA (Non-Necessary Value-Added) to identify ways to enhance efficiency based on the 8 wastes. Present a table analysis indicating which activities should be eliminated, which should be combined, which should be rearranged, and which should be simplified. Subsequently, incorporate a web-based application that aligns with the work processes.

3.4 Analysis and design of information systems

Design the functionality of the web-based application to align with the principles of waste reduction through ECRS and the 8 wastes or DOWNTIME. Eliminated activities will be promptly replaced by functions within the web-based application, reducing waiting times. Integrated activities will be streamlined, and simplified tasks will be addressed with more convenient and rapid functions. Additionally, the design will prioritize user appropriateness and requirements.

3.5 Test and evaluate

Assess whether the web-based application system meets user requirements and enhances inventory management efficiency through the installation and testing of functionality. In this research, key performance indicators for evaluation include the accuracy rate of inventory and the cost of the warehouse per sale, measured by analyzing expenses related to warehouse staff, such as salaries.

4. Results

4.1 Current state value stream mapping

From interviews and data collection, recording the process of operations from when a customer places an order until the customer receives the product, a value current state stream mapping can be drawn as follows: 1. Customers contact the sales department to express their needs for placing an order. Subsequently, the sales team negotiates the pricing and discusses various necessary details with the customers. 2. If the

customer agrees, the sales team will contact the warehouse department to inquire about the available inventory for the ordered products. Once the warehouse receives the call from the sales team, they will check the inventory levels in the internal warehouse system. After the verification is complete, the warehouse department will inform the sales team of the inventory status. 3. If the quantity of the ordered products is insufficient or if they are products that need to be newly manufactured, the sales team will issue a production order. This order is then forwarded to the sales department head for inspection and consideration for approval. Once approved, the sales team will provide the approved production order to the warehouse department. 4. The sales team calls the transportation department to check the product delivery schedule. After receiving the call from the sales team, the transportation department verifies the product delivery schedule in the transportation schedule sheet. Subsequently, they will call back the sales team to finalize the date and time for product delivery. 5. The sales team issues a transport reservation form to the transportation department. Subsequently, the transportation department takes that information to plan the transportation and records it in the product delivery schedule sheet. 6. The warehouse department receives the production order and plans the production, recording it in the production planning sheet. The plan is then forwarded to the warehouse department head for approval. Subsequently, the warehouse department sends the approved production schedule to the production department for further action. 7. The production department carries out the manufacturing of products according to the production plan. After that, the finished goods are then placed in the warehouse, and the warehouse department is notified accordingly. 8. The warehouse department notifies the sales department that the products are completed. 9. The sales department calls to inform the customers to come and collect the products or to confirm the date and time for the product delivery, as shown in Fig.1.

After that, analyze the activities' value to illustrate VA, NVA, and NNVA. It can be observed that the total time analysis for all activities is 4,449 minutes. There are 2 VA activities, taking 1,455 minutes, 10 NNVA activities, taking 102 minutes, and 5 NVA activities, which consume the most time at 2,892 minutes, as shown in Table 1.

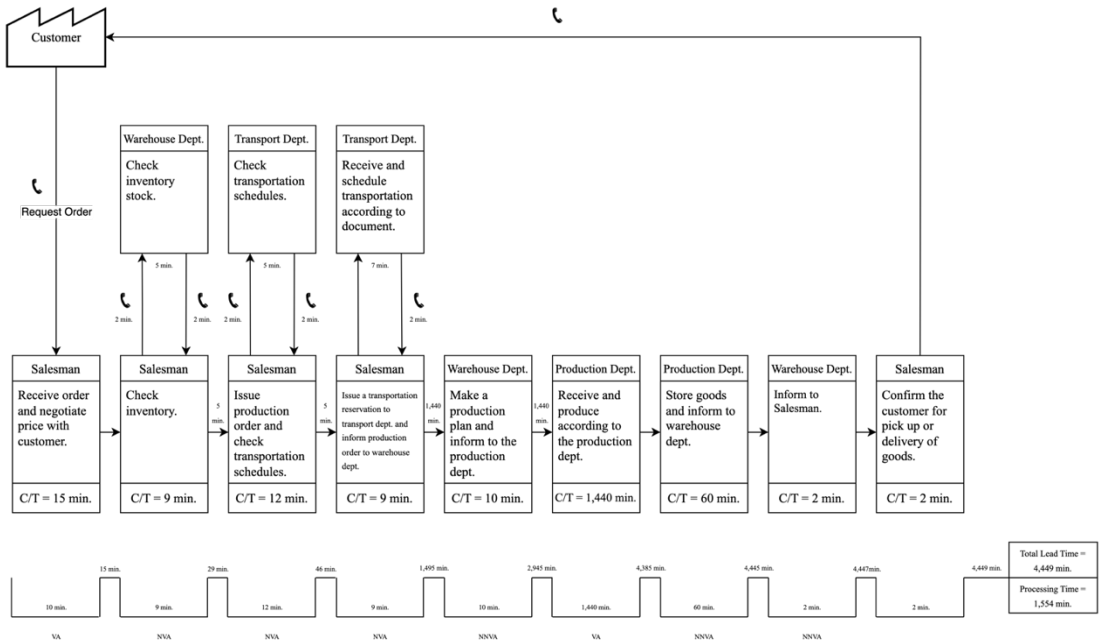

Fig. 1. The Current State Value Stream Mapping.

Table 1. The analysis of activity value (current state).

Activity	Avg. Time (min.)	Value Analysis of Activities
Sales staff receives orders, negotiates prices, and discusses necessary details with customers.	15	(1) VA
The sales staff calls the warehouse department to inquire about the available stock and inventory levels for the products ordered by the customer.	2	(1) NNVA
The warehouse department checks the inventory in the internal warehouse management system, and only the warehouse department has access to this information.	5	(2) NNVA
Waiting for the warehouse department to respond to the sales staff.	5	(1) NVA
The warehouse department calls to inform the sales staff about the quantity of available products.	2	(3) NNVA
In cases where the inventory quantity is insufficient or the ordered products are items that need to be newly produced, the sales staff or sales representative will issue a production order. After that the sales staff will call the transportation department to verify the product transportation schedule.	5	(4) NNVA
The transportation department checks the product transportation schedule in the computer system.	5	(5) NNVA
Waiting for the transportation department to respond to the sales staff.	5	(2) NVA
The transportation department calls to inform the transportation schedule and agrees on the date and time for product delivery with the sales staff.	2	(6) NNVA
The sales staff issues a delivery queue reservation to the transportation department and sends a production order to the warehouse department.	9	(7) NNVA
Waiting for the sales department head to approve the production order before sending it to the warehouse department.	1,440	(3) NVA
The warehouse department plans production and forwards it to the production department.	10	(8) NNVA
Waiting for the head of the warehouse department to approve the production plan.	1,440	(4) NVA
The production department manufactures products according to the production plan.	1,440	(2) VA
The production department stores the products in the warehouse.	60	(9) NNVA
The warehouse department calls to inform the sales department.	2	(5) NVA
The sales staff calls customers to confirm the date and time of product delivery.	2	(10) NNVA
Total time	4,449 min.	
VA	1,455 min.	
NNVA	102 min.	
NVA	2,892 min.	

Note: Time values shown in the table are obtained through investigation and interviews with employees involved in the process.

Next, analyze waste by examining the activities in the information communication process that increase costs or time in operations but do not add value to the organization. The more waste, the higher the costs. The waste analysis will be conducted based on the 8 wastes, or DOWNTIME, using NNVA and NVA for illustration. It will reveal the types of waste occurring. In total, there are 15 activities, with 5 activities related to unnecessary processing, 4 to waiting, and 6 to unnecessary motion, as shown in Table 2

Table 2. The analysis of 8 wastes.

Value Analysis of Activities (NVA, NNVA)	8 Wastes
(1) NNVA	Unnecessary Processing
(2) NNVA	Unnecessary Motion
Value Analysis of Activities (NVA, NNVA)	**8 Wastes**
(1) NVA	Waiting
(3) NNVA	Unnecessary Motion
(4) NNVA	Unnecessary Processing
(5) NNVA	Unnecessary Processing
(2) NVA	Waiting
(6) NNVA	Unnecessary Motion
(7) NNVA	Unnecessary Processing
(3) NVA	Waiting
(8) NNVA	Unnecessary Processing
(4) NVA	Waiting
(9) NNVA	Unnecessary Motion
(5) NVA	Unnecessary Motion
(10) NNVA	Unnecessary Motion

The analysis of improvement guidelines in the process will involve the use of tools to eliminate waste from the process, following the principles of waste reduction with ECRS. This will outline directions for improving NVA and NNVA activities by designing a web application and implementing it appropriately in the process, as shown in Table 3.

Table 3. Concepts for Improvement.

Value Analysis of Activities (NVA, NNVA)	Reducing Waste with ECRS	Concept for Improvement
(1) NNVA	E	Eliminate this activity by allowing sales staff to independently check the inventory quantity through the web application.
(2) NNVA	E, S	Eliminate this activity and simplify by allowing sales staff to independently check the inventory quantity through the web application system.
(1) NVA	E	This activity will be eliminated because sales staff can independently check the inventory quantity through the web application system.
(3) NNVA	E	Eliminate this activity by allowing sales staff to independently check the inventory quantity through the web application.
(4) NNVA	E, S	Simplify the process by allowing sales staff to book production queues through the web application and eliminate the activity by enabling them to check the transportation schedule on the web application.
(5) NNVA	E, S	Eliminate this activity and make it easier by allowing sales staff to be responsible for checking the transportation schedule themselves through the web application.
(2) NVA	E	This activity will be eliminated because sales staff can check the transportation schedule themselves through the web application system.
(6) NNVA	E	Eliminated because sales staff can check the transportation schedule and book transportation queues themselves through the web application system.
(7) NNVA	S	Simplified by allowing sales staff to book product transportation queues through the web application system, and the warehouse department can view or download production orders on the web application system.
(3) NVA	S	Simplified by allowing the head of the sales department to approve requests for booking product manufacturing queues from the sales staff in the web application system.

Value Analysis of Activities (NVA, NNVA)	Reducing Waste with ECRS	Concept for Improvement
(8) NNVA	S	Simplified by having the warehouse department upload the production plan into the web application system, and the production department can view or download the production plan on the web application system.
(4) NVA	-	-
(9) NNVA	-	-
(5) NVA	E	Eliminated this activity as sales staff can check the production status of products by themselves in the web application system.
(10) NNVA	-	-

After optimizing work processes using a web application, the future state value stream mapping is as follows: 1. Customers contact the sales department to express their intention to place an order. The customers specify the product requirements, including size, quantity, and other details they need. 2. The sales team will negotiate the price and other necessary details with the customer. If the customer agrees, the sales team will check the inventory of the products in the web application system. If the products are not available in sufficient quantities or if they are items that need to be produced, the sales team will proceed to make a production queue reservation in the web application system. Subsequently, the warehouse department will check the production queue reservation, plan the production, and approve the production queue reservation. This involves updating the production status and uploading the production plan in the web application system. 3. The sales team will check the product delivery schedule in the web application system, select the day and time for product delivery, and then proceed to book the product delivery queue for the chosen day and time 4. The transportation department will check the product delivery queue reservation in the web application system. 5. The transportation department approves the product delivery queue reservation and records it in the transportation schedule on the web application. 6. The production department checks the production plan on the web application and manufactures the products according to the production plan. 7. After completing the production, the finished goods are placed in the warehouse, and a notification is sent to the warehouse department. 8. The warehouse department updates the status of the products in the web application. 9. The sales department checks the production status. It notifies customers to inform them to either pick up the products or confirm the scheduled delivery date and time previously agreed upon with the customer. It can be observed that before process improvement, the total time was 4,449 minutes, and after improvement, the total time was 2,982 minutes. The time reduction is 67.03%**.** The future state value stream mapping using the web application is shown in Fig. 2.

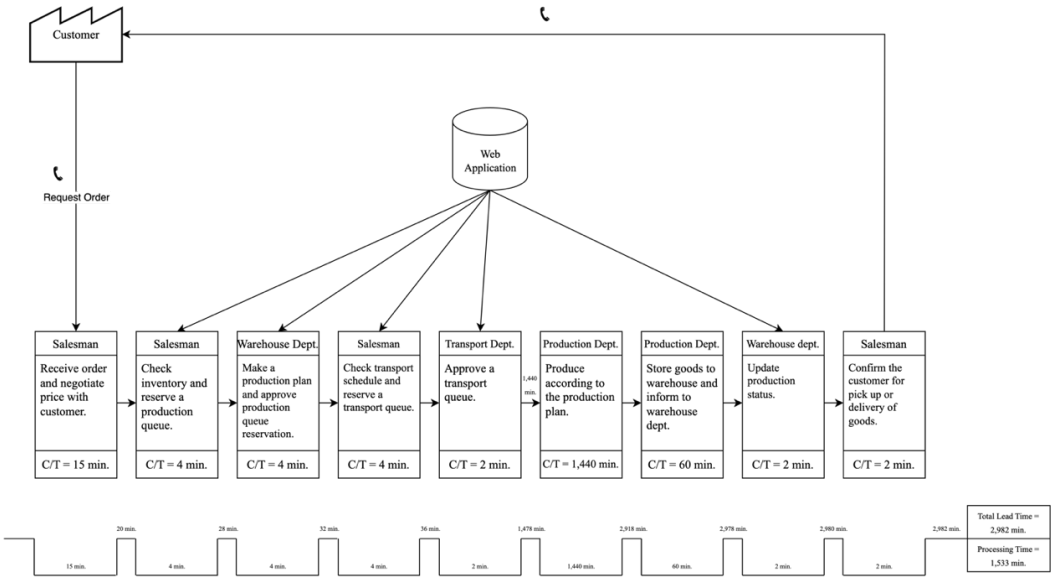

Fig. 2. The Current State Value Stream Mapping.

In addition to the reduced total time, NVA activities, which should be eliminated, have also decreased. Originally, 5 NVA activities were taking 2,892 minutes, but after the reduction, there are now 3 NVA activities taking 1,449 minutes, accounting for 50.10%. Moreover, NNVA activities, which are necessary but do not add value, have decreased as well. Initially, 10 NNVA activities were taking 102 minutes, but after the reduction, there are now 7 NNVA activities taking 78 minutes, accounting for 76.47%. The details are shown in Table 4.

Table 4. The analysis of activity value (future state).

Activity	Avg. Time (min.)	Value Analysis of Activities
Sales staff receives orders, negotiates prices, and discusses necessary details with customers.	15	(1) VA
Waiting for the head of the sales department to review and approve the customer order.	5	(1) NVA
Sales staff check the available stock and issue a production queue reservation through the web application system.	4	(1) NNVA
Waiting for the warehouse department checks the production queue reservations for the products through the web application system.	4	(2) NVA
The warehouse department makes a production plan and approves the status of production queue reservations.	4	(2) NNVA
Sales staff check the transportation schedule and book transportation queues through the web application system.	4	(3) NNVA
The transportation department verifies and approves the status of the booked transportation queues through the web application system.	2	(4) NNVA
Waiting for the production department to checks production orders and prepare for product manufacturing.	1,440	(3) NVA
The production department manufactures products according to the production plan.	1,440	(2) VA
The production department stores the products in the warehouse.	60	(5) NNVA
The warehouse department updates the production status in the web application system.	2	(6) NNVA
The sales staff calls customers to confirm the date and time of product delivery.	2	(7) NNVA
Total time		2,982 min.
VA		1,455 min.
NNVA		78 min.
NVA		1,449 min.

4.2 Inventory accuracy rate

In evaluating the inventory accuracy rate, it will be measured by the percentage difference between the actual inventory quantity and the recorded inventory quantity in the system. This will be achieved by recording the quantity of the top 10 best-selling products both in the system and the actual count, before (the year 2022) and after (the year 2023). Using the web application in this research, the calculation formula is based on the Industrial Logistics Performance Index (ILPI) for warehouse management activities within the dimension of reliability. The formula for calculating stock difference is referenced from the "Handbook for Evaluating Logistics Management and Supply Chain Potential" (in Thai) [9]. The formula for calculating is

$$\text{Stock Diff}(\%) = \frac{(\text{Counted Qty} - \text{Stock Level}) \times 100}{\text{Stock Level}}, \quad (4.1)$$

where Counted Quantity is the Actual Stock Quantity refering to the counted amount of product in stock. Stock Level is the recorded inventory amount in the system.

From collecting data over the entire 3-month period and calculating from the previous formula, the results are as follows: The percentage difference between the actual inventory quantity and the recorded inventory quantity in the system, with a decrease in the discrepancy percentage, for July in the year 2022 was 262.96%, and in the year 2023, it decreased to 30.24%, reducing by 232.72%. For August, in the year 2022, it was 17.90%, and in the year 2023, it decreased to 15.26%, reducing by 2.64%. Lastly, for September, in the year 2022, it was 41.75%, and in the year 2023, it decreased to 9.93%, reducing by 31.82%. The average percentage difference between the actual inventory quantity and the inventory quantity recorded in the system in all three months is as follows: in 2022 it was 107.54%, and in 2023 it decreased to 18.48%. It can be noted that the accuracy of the inventory quantity has been improved. An improvement of 89.06% after using the web application. An example of an inventory quantity accuracy comparison table is shown in Table 5.

Table 5. Comparison of Inventory Accuracy.

Product code	August						Difference of Diff (%)
	Year 2022 (without WebApp)			Year 2023 (with WebApp)			
	Stock Level	Daily Q'ty	Difference (%)	Stock Level	Daily Q'ty	Difference (%)	
A13-050-0504-0035-0395	780	1,533	96.54	1,780	2,009	12.87	83.67
A13-050-0404-0035-0345	1,293	1,101	-14.85	1,525	1,699	11.41	3.44
A13-050-0404-0035-0295	1,434	1,319	-8.02	1,375	1,410	2.55	5.47
A13-050-0404-0035-0300	1,022	996	-2.54	1,488	1,624	9.14	-6.60
A13-050-0504-0035-0400	860	945	9.88	1,330	1,200	-9.77	0.11
A13-050-0604-0035-0200	1,203	1,122	-6.73	2,838	3,011	6.10	0.64
A13-050-0404-0035-0350	570	696	22.11	1,295	1,293	-0.15	21.95
A13-050-0404-0035-0195	1,114	962	-13.64	612	764	24.84	-11.19
A13-050-0404-0035-0245	952	885	-7.04	1,213	1,289	6.27	0.77
A13-050-0404-0035-0335	30	61	103.33	47	89	89.36	13.97
Avg.			17.90			15.26	2.64

4.3 Warehousing cost per sale

The evaluation of performance with warehousing cost per sale will be measured by the reduced expenses in terms of salary or wages of warehouse staff. Comparing the labor costs from the changed workflow both before and after implementing the web application. The process before implementing the web application involved warehouse staff recording the quantity of products produced from the subcontractor's production documents in the daily stock

ledger. They then recorded the stock quantity in an Excel file, which was subsequently sent to the administration for data entry into the WMS system. This process took approximately 5 hours per day, resulting in an expense of 60,500 Baht per year. The process after implementing the web application involves warehouse staff recording the number of products produced from the subcontractor's production documents in an Excel file and uploading the file into the web application system. The file is then forwarded to the administration for data entry into the WMS system. This process takes approximately 3.5 hours per day, resulting in an expense of 44,000 Baht per year. This represents a reduction of 16,500 Baht per year or 27.27%, as shown in Tables 6 and 7. The working hours are 9 hours per day and 242 days per year.

An example of the display of the web application's screen and function in this research is shown in Figs. 3-4.

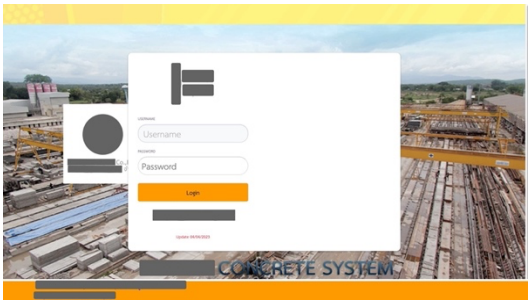

Fig. 3. The login page of the web application.

Fig. 4. The web application page for displaying product details.

Table 6. Warehousing Cost Current State (Salary).

Activity	Activity Time (Hr.)	Salary (THB./month)	Salary per Day (THB.)	Expenses for each activity per day (THB.)	Expenses for each activity per year (THB.)
Record the quantity of produced goods in the daily inventory ledger.	2	9,000	409.09	91	22,000
Record the stock quantity in an Excel file.	1.5	9,000	409.09	68	16,500
Record the stock quantity in the WMS system.	1.5	12,000	545.45	91	22,000
Total	5	30,000	1,363.64	250	60,500

Table 7. Warehousing Cost Future State (Salary).

Activity	Activity Time (Hr.)	Salary (THB./month)	Salary per Day (THB.)	Expenses for each activity per day (THB.)	Expenses for each activity per year (THB.)
Record the stock quantity in an Excel file and upload it to the WebApp.	2	9,000	409.09	91	22,000
Record the stock quantity in the WMS system.	1.5	12,000	545.45	91	22,000
Total	3.5	21,000	954.55	182	44,000

5. Conclusion

This research focuses on improving warehouse management efficiency in a precast concrete manufacturing company using value stream mapping tools and the ECRS technical process to reduce waste in the process. Subsequently, the obtained guidelines were used to design and develop

a web application prototype suitable for operational use. The study revealed that before the process improvement, the total time for all activities was 4,449 minutes. After the improvement, the total time was reduced to 2,982 minutes, resulting in a time reduction of 1,467 minutes or 67.03%.

Regarding the evaluation based on inventory accuracy rate, it was found that in the current workflow, there was a stock difference with an average deviation of 107.54%. After implementing the web application in the workflow, the average deviation dropped to 18.48%, a significant reduction from the current workflow of 89.06%.

Furthermore, when evaluating the performance with warehousing cost per sale, it was found that the current workflow incurred an annual expense of 60,500 Baht for warehouse staff salaries. After testing the web application in the workflow, the annual expense for warehouse staff salaries was reduced to 44,000 Baht, a decrease of 16,500 Baht or 27.27%. Thus, the proposed concepts of using value stream mapping tools and the ECRS technical process, along with the implementation of a web application, proved to be effective tools in warehouse management, enhancing overall efficiency.

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