How to cite this article: Sukit Amnuaycheewa and Aeknaree Toomphol. (2025). Strategic Optimization of Tank Cleaning for Enhanced Dry Dock Satisfaction: A Case Study of the Large Oil Tanker Tsurusaki. *Journal of Logistics and Supply Chain Operations, 11*(2), 150-167. https://doi.org/10.53848/jlsco.v11i2.273797

Received:	December	12, 2023
Revised:	February	27, 2024
Accepted:	May	14, 2025

Strategic Optimization of Tank Cleaning for Enhanced Dry Dock Satisfaction: A Case Study of the Large Oil Tanker Tsurusaki

Sukit Amnuaycheewa[1]* and Aeknaree Toomphol[2]

Abstract

This research aims to achieve three objectives: 1) To study the preparation process for entering the dry dock for M.T. Tsurusaki, 2) To investigate the issues concerning the preparation for entering the dry dock for the repair of M.T. Tsurusaki, and 3) To enhance the efficiency of operations on M.T. Tsurusaki in terms of reducing costs and time in conducting tasks. A qualitative research approach was employed, involving a population group of 15 ship crew members from both the deck and engine departments, to prepare for the study, focus group discussions and brainstorming sessions were conducted. Moreover, the lean system was introduced to eliminate waste in the work process. Process changes resulted in a reduction of waiting time by streamlining tasks that could be done simultaneously, without compromising safety standards. Based on the experience of ship crew members, the introduction of the lean system led to a reduction in working hours from 156 to 120, a decrease of 36 hours. Fuel consumption in the studied process decreased from 441.59 MT to 303.32 MT, a reduction of 138.27 MT. Calculating operating costs based on a fuel price of 585 USD/MT in May 2023, fuel expenses during operation decreased from 258,330.15 USD to 177,442.20 USD, resulting in a cost reduction of 80,887.95 USD. In summary, this research demonstrates an effective approach to enhancing work efficiency on large oil tankers while reducing fuel consumption, aligning with the stated objectives.

Keywords: Tank cleaning procedure, Crude oil washing, Dry dock, Oil tanker, Crude oil
Type of Article: Research Article

* Corresponding author
[1] Student of Master of Science Logistics and Supply Chain Management, Southeast Bangkok University, E-mail: amnuaycheewa_seaman@hotmail.com
[2] Associate Dean-Academic Affairs Faculty of Logistics and Aviation Technology, Southeast Bangkok University, E-mail: aeknaree_t@southeast.ac.th

ผ่านการรับรองคุณภาพจากศูนย์ดัชนีการอ้างอิงวารสารไทย (TCI.) อยู่ในกลุ่ม 2 สาขามนุษยศาสตร์และสังคมศาสตร์

กลยุทธ์การเพิ่มประสิทธิภาพการล้างถังสินค้าเพื่อความพึงพอใจในการเข้าอู่ซ่อมเรือ กรณีศึกษา เรือบรรทุกน้ำมันขนาดใหญ่ ซึรุซากิ

สุกิจ อำนวยชีวะ[1]* และ เอกนรี ทุมพล[2]

บทคัดย่อ

การวิจัยนี้มีวัตถุประสงค์เพื่อ 1) เพื่อศึกษากระบวนการเตรียมความพร้อมเพื่อเข้าอู่ซ่อมเรือของเรือบรรทุกน้ำมันขนาดใหญ่ M.T. Tsurusaki, 2) เพื่อศึกษาปัญหาการเตรียมความพร้อมเพื่อเข้าอู่ซ่อมเรือของเรือบรรทุกน้ำมันขนาดใหญ่ M.T. Tsurusaki และ 3) เพื่อเพิ่มประสิทธิภาพการทำงานบนเรือบรรทุกน้ำมันขนาดใหญ่ M.T. Tsurusaki ในมิติของการลดต้นทุนและระยะเวลาในการดำเนินงาน ใช้รูปแบบในการวิจัยเชิงคุณภาพ โดยใช้กลุ่มประชากรคือคนประจำเรือที่ทำงานบนเรือทั้งแผนกปากเรือและแผนกห้องเครื่องจำนวน 15 คน โดยอาศัยการสนทนาแบบกลุ่มและมีการประชุมระดมสมองเพื่อเตรียมการทำงานและจึงได้มีการนำเอาระบบลีนเข้ามาช่วยกำจัดความสูญเปล่าในขั้นตอนการทำงาน ผลของการปรับเปลี่ยนขั้นตอนในการทำงานสามารถลดเวลาในการรอคอย หากขั้นตอนหรือกระบวนการไหนที่สามารถทำงานพร้อมกันได้ก็ทำงานร่วมกันแต่ในส่วนของมาตรฐานความปลอดภัยในการทำงานนั้นจะต้องไม่ลดลงจากขั้นตอนเดิม ซึ่งที่มาในการนำระบบลีนมาใช้เนื่องจากมีการนำประสบการณ์ของคนประจำเรือมาประยุกต์ใช้ในขั้นตอนการทำงานซึ่งผลจากการปรับเปลี่ยนนั้นจะพบว่าระยะเวลาในการทำงานช่วงที่ศึกษานั้นลดลงจาก 156 ชั่วโมง ลดลงเหลือ 120 ชั่วโมงซึ่งลดลงไปทั้งสิ้น 36 ชั่วโมง มีการใช้เชื้อเพลิงตามขั้นตอนเดิมที่ศึกษา 441.59 MT ลดลงเหลือ 303.32 MT ซึ่งลดการใช้เชื้อเพลิงลงไปได้ 138.27 MT โดยเมื่อคำนวณต้นทุนในการดำเนินการโดยราคาเชื้อเพลิงอ้างอิงเดือน พฤษภาคม 2023 ราคาจะอยู่ที่ 585 USD/MT ซึ่งจะคิดเป็นค่าเชื้อเพลิงในขั้นตอนการดำเนินงานอยู่ที่ 258,330.15 USD หลังจากปรับปรุงรูปแบบการทำงานทำให้ค่าใช้จ่ายของเชื้อเพลิงจะลดลงเหลือ 177,442.20 USD ทำให้ค่าใช้จ่ายลดลง 80,887.95 USD ซึ่งสามารถสรุปได้ว่าแนวทางในการเพิ่มประสิทธิภาพในการทำงานบนเรือบรรทุกน้ำมันขนาดใหญ่และการใช้เชื้อเพลิงที่ลดลงซึ่งตรงตามวัตถุประสงค์ที่ตั้งไว้

คำสำคัญ: ขั้นตอนการล้างถังสินค้า, การล้างถังสินค้าด้วยน้ำมันดิบ, การเข้าอู่ซ่อมเรือ, เรือบรรทุกน้ำมัน, น้ำมันดิบ

ประเภทบทความ: บทความวิจัย

* ผู้รับผิดชอบหลัก

[1] นักศึกษาหลักสูตรวิทยาศาสตรมหาบัณฑิต สาขาการจัดการโลจิสติกส์และโซ่อุปทาน คณะโลจิสติกส์และเทคโนโลยีการบิน มหาวิทยาลัยเซาธ์อีสท์บางกอก, อีเมล: amnuaycheewa_seaman@hotmail.com

[2] อาจารย์ประจำหลักสูตรวิทยาศาสตรมหาบัณฑิต สาขาการจัดการโลจิสติกส์และโซ่อุปทาน คณะโลจิสติกส์และเทคโนโลยีการบิน มหาวิทยาลัยเซาธ์อีสท์บางกอก, อีเมล: aeknaree_t@southeast.ac.th

ผ่านการรับรองคุณภาพจากศูนย์ดัชนีการอ้างอิงวารสารไทย (TCI.) อยู่ในกลุ่ม 2 สาขามนุษยศาสตร์และสังคมศาสตร์

1. Introduction

In the current context, energy is a crucial driver of every country's economy, leading to an increasing and continuous demand for energy resources. Department of Energy Business has revealed that the average consumption of fuel oil in Thailand from January to August 2023 was 154.88 million liters per day, marking a 2.3 % increase compared to the corresponding period the previous year (Nutchayar, 2023). Despite efforts to promote the use of clean or alternative energy sources such as fossil fuels, the demand for fuel has not decreased. All types of oil imports during this period averaged 1,042,520 barrels per day, an increase of 1.3 %. The value of oil imports reached 92,532 million baht per month compared to the previous year, with crude oil imports at 968,409 barrels per day, an increase of 1.0 %. The value of crude oil imports reached 87,481 million baht per month. For refined oil products (basic gasoline, diesel, kerosene, aviation fuel, and LPG), (Siddiqui et al., 2018) imports increased to 74,111 barrels per day, marking a 5.8 % increase, with a total value of 5,051 million baht per month (Nutchayar, 2023).

Historically, Thailand used to rely on foreign companies to transport crude oil. However, since 1987, Prima Marine Co., Ltd. has been a major player in the transportation of crude oil, starting as a small company and now operating ships with Thai crew members. While ship management may involve foreign companies, Thailand intends to take advantage of the benefits. This transportation of crude oil is crucial to meet the demands of the six refineries in Thailand (Office of Strategic and Planning Division, Ministry of Energy, 2015). Additionally, there is a transportation of refined petroleum products, both domestically and internationally, with large oil tankers bringing crude oil from the Middle East to Thailand to satisfy the increasing demand for oil and its derivatives. Ensuring the proper maintenance of these ships and equipment is essential not only for the energy security of the nation but also for the stability of the energy supply in the ASEAN region, as Thailand plays a vital role as a regional energy hub.

Crude oil (Fakher et al., 2020) is a highly hazardous commodity, making the safety of these ship paramount. Any damage to the ship, cargo, and crew can lead to environmental disasters with incalculable costs to natural resources, aquatic life, and coastal areas. Therefore, ship maintenance and keeping ships and equipment in good working condition are vital to ensuring the safety and security of both the crew and the environment.

In this research, excessive time spent cleaning cargo tanks in preparation for dry dock, as part of ship repairs, can lead to both time and cost inefficiencies. If it is possible to reduce both the time and fuel consumption during work, it would enable the company to return crude oil transportation to the refinery in Thailand more promptly to meet the demand.

2. Research's objectives

1. To study the preparation process for entering the dry dock for M.T. Tsurusaki.

2. To investigate the issues concerning the preparation for entering the dry dock for the repair of M.T. Tsurusaki.

3. To enhance the efficiency of operations on M.T. Tsurusaki in terms of reducing costs and time in conducting tasks.

3. Literature review

3.1 Lean system for improving organizational efficiency

Management principles mean managing an organization in a way that allows for continuous development, developing and proposing a model that explores the role of intra and inter-organizational learning, lean product development, lean manufacturing practices, and zero waste practices in advancing circular economy target performance and organizational identity among small and medium enterprises in an emerging economy (Yaw et al., 2021). The application of various management is essential, such as designing workflow processes and managing and motivating human resources, which are crucial for the organization's growth. Support from leadership plays a significant role in driving the organization's self-improvement.

3.2 The 8 Wastes

The main tools in managing lean systems, include: (Sulaiaman et al., 2022).

1) Defect: producing any product that is not suitable for use for whatever reason such as defective materials and components or produced not per specification.

2) Overproduction: manufacturing extra products that are not required or have no customer demand.

3) Delay: delay time for employees such as equipment downtime, delay in processing, being out of stock of materials, or production equipment not ready.

4) Transportation: the movement of components and products between stations that are not required to reach customers' needs.

5) Overprocessing: the addition of unrequired processes to produce a product or utilizing a more capable machine when a simpler one would be sufficient for the task at hand.

6) Inventory: inventory waste is all the materials, components, or products in storage for longer than necessary.

7) Underutilized skills: moreover, employees could utilize their existing knowledge to achieve the desired future states of optimized quality products and processes.

8) Motion: motion waste is unnecessary human movement, whether on the shop floor or micro-movement within a workstation (Sulaiaman et al., 2022).

Increasing efficiency in the lean system involves reducing waste, and all kinds of loss, as well as unnecessary costs and processes that, if not corrected, can lead to unforeseen inefficiencies.

3.3 Shipboard's Working Procedure

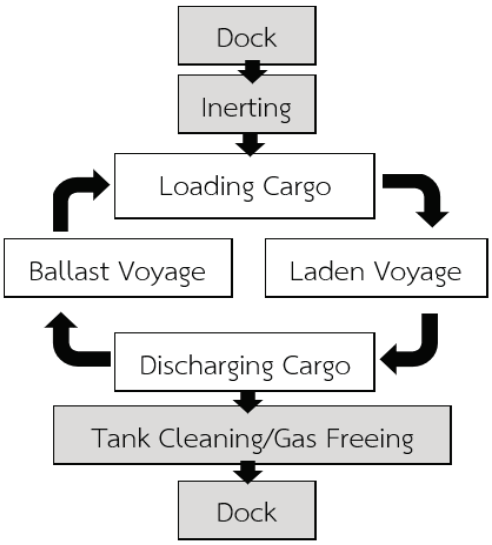


Figure 1 One round of a typical voyage.

Figure 1, depicts the entire work process of the vessel, from shipbuilding to entering the dry dock for repairs, as follows:

1) Dock entering the shipyard is the first process of maritime transportation, where the ship being constructed must meet the specified quality and standards to obtain the necessary documentation for lawful and international compliance.

2) Inerting is the initial step of transportation when the ship departs from the shipyard to load cargo. It involves reducing the oxygen levels in the tanks below the ignition range for safety when leaving the shipyard (Muhammet et al., 2021).

3) Loading cargo involves preparing and calculating the ship's supplies, fresh water, food, and other necessities based on information received about the origin, quantity of goods, and destination for transportation.

4) Laden voyage refers to the voyage when the ship has received the cargo. During this voyage, care must be taken to prevent damage or loss of cargo, as well as to protect the ship and the environment.

5) Discharging cargo occurs when the ship arrives at the destination port. Cargo is discharged according to the instructions and quantities specified by the charterer. The ship receives instructions from the port authorities on the order of discharging and other safety procedures.

6) Ballast voyage is a voyage where the ship is ballasted with seawater and carries no cargo. This type of voyage allows for ship maintenance, equipment checks, and readiness for the next loading voyage (Dock et al, 2019).

7) Tank cleaning/Gas freeing involves cleaning (Aydin et al., 2021) and ventilating cargo tanks after the ship has completed its final cargo voyage before entering the shipyard for inspection and repairs, as required by international regulations to ensure safe operation in all areas (Aydin et al., 2021). The use of a lean system reduces operational steps, maintaining safety without compromise.

8) Dock/Shipyard refers to entering the shipyard according to a periodic schedule. The vessel must enter the shipyard twice in five years, according to the regulations, as shown in Figure 2, in preparation for dry dock.

Figure 2 M.T. Tsurusaki (VLCC).

4. Methodology

4.1 Research method

Qualitative research methodologies were used in the study; documentary research entailed gathering data from prior employment records or comprehending the core operations of a business; focus group discussions involved sharing experiences, exchanging ideas, and conversing. With a flexible and open-ended research approach, the researcher gathered and examined data from documents and developed a working procedure based on information shared in group discussions.

4.2 Population and sample

The following conclusions were reached from data processing used in the qualitative research approach. The study's sample group comprised 15 individuals, including the captain who held overall command, the chief officer who oversaw cargo operations, the chief engineer who oversaw the engine department, the second engineer who oversaw maintenance machinery, and the deck crews who collaborated with senior officers.

4.3 Research instruments

This time, the instruments employed for data collecting include focus group discussions, open-ended survey questions, work manuals, books, journals, company-related recommendations, and international agreements. Then, depending on the study's conclusions, we evaluate the workflow, try out

new techniques, and record the procedure for future evolution.

4.4 Data collection

The data collection process used for this study includes guidelines for gathering data, such as collecting information from ship operation manuals, historical records of previous ship preparations for repair in dry docks as safety procedures and tank cleaning operations, and collecting data through focus group discussions.

4.5 Data analysis

For the researcher, there are several steps in the qualitative data analysis process. The initial thing they do is compare the recorded group discussions to the company's documented procedures. This involves assessing and improving procedures for efficiency. Information from the group discussions is applied to the work process for experimentation.

In its conclusion, the analysis outputs study-specific answers and assesses how well the workflow steps succeeded, as shown in Figure 3, the tank cleaning procedure has one reduced process.

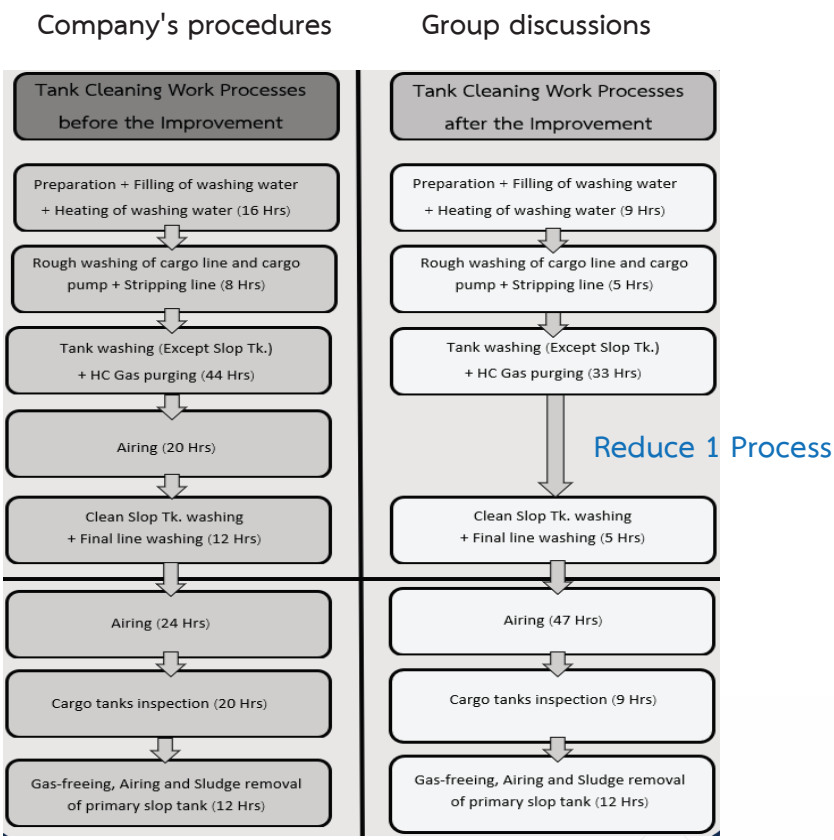


Figure 3 Tank cleaning's flowchart.

5. Results

5.1 The study's findings regarding work time

The process of cleaning cargo tanks initially consists of 16 steps. However, after the implementation of efficiency improvements, consolidating workflow processes proved to be effective, reduced waiting times, decreased overall work duration, and had a direct impact on resource usage, and costs, and reduced the time it takes for the ship to operate.

1) Crude oil washing at the previous discharging terminal, the time taken for COW (Mislav et al., 2022) remained similar before and after process improvements.

2) Filling of washing water involves transferring seawater from WBT No.1 (P/S) to slop tank (P/S) using gravity. The slop tank at the stern of the ship is lower than WBT No. 1 at the bow.

3) The heating of washing water in the tank cleaning process, especially for removing oil residues, requires high-temperature water. In the original process, it took 126 hours, whereas, after improvements, it took 55 hours, resulting in a 71-hour difference as shown in Table 2, Summary of the working process comparison between before and after-improvement format (process by process).

4) Rough washing on the cargo line and cargo pump, both methods took the same amount of time, 4 hours, for this step.

5) Line washing and valve flushing, both methods took the same amount of time, 4 hours, for this step.

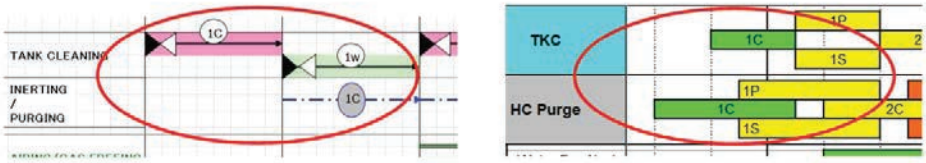
6) Tank washing in the original process, there was a focus on cleaning tank surfaces, taking 6 rounds with a total time of 4 hours per tank. After improvements, the focus shifted to wider cleaning with 2 initial rounds followed by floor cleaning in 5 rounds, taking a total of 3 hours per tank, and reducing the time by 1 hour per tank as shown in Figure 4, Comparison of tank cleaning patterns.

Before
6 Steps to the cleaning process.

After
5 Steps to the cleaning process.

Figure 4 Comparison of tank cleaning patterns.

7) HC gas purging (Maljković et al., 2022) The original process took 40 hours for this step, while after improvements, it took 37 hours, resulting in a 3-hour reduction as shown in Figure 5, initially, tank cleaning and purging are carried out independently; but, in the end, they collaborate.



Before
Tank cleaning and purging are done separately.

After
Combined with tank cleaning and purging.

Figure 5 Comparisons of tank cleaning and purging procedures.

8) Airing, both methods took the same amount of time, 60 hours, for this step.

9) Settling and discharging water, the time taken in this step remained the same in both the original and improved methods.

10) Final line washing in the original process, took 4 hours, while after improvements, it took 2 hours, reducing the time by less than 2 hours.

11) Sludge removal, external contractors carry out this process, which must be completed before the ship enters the dock, as shown in Figure 6, sludge in the cargo tank and solidified congealed oil at the bottom of the cargo tank, which has formed a cohesive mass.

Figure 6 Sludge in the cargo tank

12) Slop removal, external contractors require an equal amount of time to complete both methods, which is 7 hours in this step.

13) Primary slop tank washing, both methods take the same amount of time, which is 7 hours in this step.

14) Primary slop tank gas freeing airing and sludge removal, both methods take the same amount of time, which is 7 hours in this step.

15) Final line stripping, the same time before and after the modification.

16) Acquisition of gas-free certificates which requires checking the tank's atmosphere

suitability for work and ensuring no hazardous gases remain. This must be done before the ship enters dry dock.

17) The overall difference in working time, for all tasks is 156 hours. After the modification, the total working time is 120 hours, with a difference of 36 hours, mainly in hydrocarbon gas venting and cargo tank cleaning, accounting for 23.07%.

From the data and calculations, it was found that the use of fuel oil in cargo tank cleaning can be reduced by 138.27 MT, the cost of fuel oil is reduced by 80,887.95 USD, accounting for 31.31%, and the working time is reduced by 36 hours.

Table 1 Fuel consumption of M.T. Tsurusaki.

Item	Description	Fuel consumption (MT/day)		
		Seagoing passage	Special activity	Summary
1	The rate of fuel consumption during passage and tank cleaning.	40.5 MT/day	40.0 MT/day	80.5 MT/day
2	The rate of fuel consumption during passage and ballast exchange.	40.5 MT/day	5.0 MT/day	45.5 MT/day

From Table 1, the fuel consumption of the vessel can be separated into two categories: seagoing passage and special tasks other than seagoing passage, such as tank cleaning and ballast exchange, which need 40.0 MT and 5.0 MT of fuel per day, respectively.

Fuel consumption for seagoing passage during tank cleaning is 40.5+40.0 = 80.5 MT/day (yellow).

Fuel consumption during seagoing passage during ballast exchange is 40.5 + 5.0 = 45.5 MT/day (green).

Table 2 Summary of the working process comparison between before and after-improvement format (process by process).

Item	Description	Before	After	Comparison
1	Crude oil washing	Comply with regulation	Comply with regulation	Same amount of time.
2	Filling of washing water	2 Hrs. Qty 3,500 m^3	2 Hrs. Qty 2,250 m^3	Decreased Qty 1,250 m^3

Table 2 Summary of the working process comparison between before and after-improvement format (process by process).

Item	Description	Before	After	Comparison
3	Heating of washing water	126 Hrs.	55 Hrs.	Decreased 71 Hrs.
4	Rough washing of cargo line and cargo pump	4 Hrs.	4 Hrs.	Same amount of time.
5	Line washing and valve flushing	4 Hrs.	4 Hrs.	Same amount of time.
6	Tank washing	44 Hrs.	33 Hrs.	Decreased 11 Hrs.
7	HC gas purging	40 Hrs.	37 Hrs.	Decreased 3 Hrs.
8	Airing	60 Hrs.	60 Hrs.	Same amount of time.
9	Settling and discharging water	24 Hrs.	24 Hrs.	Same amount of time.
10	Final line washing	4 Hrs.	2 Hrs.	Decreased 2 Hrs.
11	Sludge removal	Contractor	Contractor	Depend on contractor
12	Slop removal	Contractor	Contractor	Depend on contractor
13	Primary slop tank washing	7 Hrs.	7 Hrs.	Same amount of time.
14	Primary slop tank gas freeing airing and sludge removal	7 Hrs.	7 Hrs.	Same amount of time.
15	Final line stripping	7 Hrs.	7 Hrs.	Same amount of time.
16	Acquisition of gas-free certif-icates	Safety condition	Safety condition	Safety condition after checking

Table 2, presents a comparison between the process steps before and following work improvement. This completely separates every task. It can only complete that process and not require any additional actions within the duration shown in the table, which consists of 16 processes.

Table 3 Summary of the working process comparison between before and after-improvement.

Item	Description	Before	After	Comparison
1	Preparation + Filling and heating of washing water	16 Hrs.	9 Hrs.	Decreased 7 Hrs.
2	Rough washing of cargo line and cargo pump	8 Hrs.	5 Hrs.	Decreased 3 Hrs.
3	Tank cleaning + Purging	44 Hrs.	33 Hrs.	Decreased 11 Hrs.

Table 3 Summary of the working process comparison between before and after-improvement.

Item	Description	Before	After	Comparison
4	Airing	20 Hrs.	-	Decreased 20 Hrs.
5	Slop tank cleaning + Final flush	12 Hrs.	5 Hrs.	Decreased 7 Hrs.
6	Airing	24 Hrs.	47 Hrs.	Increased 13 Hrs.
7	Tank inspection	20 Hrs.	9 Hrs.	Decreased 11 Hrs.
8	Slop discharging	12 Hrs.	12 Hrs.	Same amount of time.
	Total	**156 Hrs.**	**120 Hrs.**	**Decreased 36 Hrs.**

Table 3, is a comparison table before and after the work improvement. Each step will operate concurrently in many processes, as indicated in Table 2, which shows that there were 8 steps before the work improvement and 7 steps (a 1-step reduction) following the improvement.

Table 4 The fuel cost of the M.T. Tsurusaki (calculated per actual working hour onboard).

Item	Description (Working pattern)	Working time		Fuel oil(MT)		Total cost (USD)
		Hour	Day	Con-sumption	Fuel price (USD/MT)	
Before	Traditional 80.5 MT/day	100	4.17	335.42	585	196,220.70
	Improvement 45.5 MT/day	56	2.33	106.17	585	62,109.45
	Summary	156	6.50	441.59	585	258,330.15
After	Traditional 80.5 MT/day	52	2.17	174.40	585	102,024.00
	Improvement 45.5 MT/day	68	2.83	128.92	585	75,418.20
	Summary	120	5.0	303.32	585	177,442.20

Summary	Before	After
Consumption 80.5 MT/day	100 Hrs.	52 Hrs.
Consumption 45.5 MT/day	56 Hrs.	68 Hrs.
Total working time (Hrs.)	156	120
Total consumption (MT)	441.59	303.32
Total bunker price (USD)	258,330.15	177,442.20
Time reduction (Hrs.)		-36
Fuel reduction (MT)		-138.27
Cost reduction (USD)		-80,887.95

Table 4 The fuel cost of the M.T. Tsurusaki (calculated per actual working hour onboard).

Item	Description (Working pattern)	Working time		Fuel oil(MT)		Total cost (USD)
		Hour	Day	Con-sumption	Fuel price (USD/MT)	
Time reduction ratio (%)						-23.07
Fuel reduction ratio (%)						-31.31
Cost reduction ratio (%)						-31.31

Note: The fuel prices used for calculation are as of May 2023.

Each process performs every step of the procedure independently, as shown in Table 2. Before and after the improvement, the ship is unable to perform process-by-process. However, several simultaneous processes from Table 3 will be included in the procedure. As in the cases of tank cleaning and ballast exchange, it will be possible to divide each procedure for fuel consumption by Table 1. Efficient fuel consumption is efficiently summarized by comparing work procedures before and after work. Table 4 shows the results of separating the fuel consumption rate before and after the modification. It was possible to reduce the time required for each step of the process. Additionally, it also led to a reduction in fuel consumption, which is a significant cost in line with the objectives of this study.

8. Discussion and conclusions

8.1. To study the preparation process for entering the dry dock for M.T. Tsurusaki.

After a study of the procedures that are carried out on large oil tankers to prepare vessels for dry dock, several different working patterns were identified: 1) The traditional working pattern as per the company's guidelines same as documentary research, and 2) The working pattern after improvement emerges after completing group discussions and modifying the lean system. It can use the summary that follows:

1) Traditional working pattern as per company guidelines: Even inexperienced crews can follow this simple procedure. With a standardized workflow that complies with all company vessels, it is a fundamental and extremely safe operating procedure. Experts at every stage of the process, the company's staff directs and controls the crews.

(1) Advantages: The traditional or company-prescribed method is a high-safety procedure because it needs to be straightforward and easily understood. It must apply to every vessel in the company since each ship may have different equipment, cargo handling methods, or layouts. However, the established procedure should ensure safe operations, and anyone with basic knowledge of ship equipment can follow it immediately.

(2) Disadvantages: It is a time-consuming process because each step must be completed before moving on to the next one, leading to increased time spent. This, in turn, raises the fuel costs associated with the operation. If a vessel enters a repair dock on short notice, there may not be enough time to prepare the ship adequately before entering the dock.

2) Working pattern after improvement with the lean system:

The process arises from the experiences of the captain, and crew, who come together to hold focus group discussions and plan, presenting ideas based on their individual experiences to ensure that the work aligns with or closely resembles the most significant constraints.

(1) Advantages: After implementing changes and incorporating the lean system, you will find that it can significantly reduce costs for the company and keep operations on schedule. Even with streamlined processes, safety during work does not decrease, not even by a small margin. Holding meetings before making these improvements encourages everyone on board to express their thoughts, share experiences, and listen to one another's opinions, ultimately leading to visible results.

(2) Disadvantages: The work process is specific to each ship and represents a newly established process. Safety checks are crucial in this regard. If the crew members cannot understand the work process, it can affect workplace safety. The environmental consequences of oil spills or tank cleaning water incidents into the sea are potentially severe.

From studies and practical implementation, it is evident that work efficiency improves when implementing the lean system in the workflow. This results in reduced working time, aligning with the objectives set in the study and matching the research of Thantawan et al. (2020) on waste reduction in the production process of bricks: a case study of a construction material store.

8.2 To investigate the issues concerning the preparation for entering the dry dock for the repair of M.T. Tsurusaki.

After the process improvements and corrections, were necessary due to: 1) Short passage distance to the drydock, aligning with the research by Jurairat and Chitpong. (2019) on optimizing rail transportation efficiency: a case study of the Bangkok-Chiang Mai route. 2) Limited time for ship preparation at the dry dock, necessitating the minimization of work time. 3) The need to maintain safety standards, especially because the transported goods are hazardous materials with toxic gases. In general, security should be comprehensive, even in the face of changed working processes. However, security should not be compromised. The study involved researching various theories and manuals to find solutions. Group discussions were used to identify suitable work methods or procedures based on experience. The application of the lean system served as guidelines for improvement.

8.2.1 To increase the efficiency of work on M.T. Tsurusaki and ensure that operations are carried out swiftly within the set timeframes, lean system implementation resulted in process improvements. This makes it possible to reduce the number of work processes required and guarantees that work will be completed in or close to the time frame specified. The docking process is a critical operation that needs to be performed swiftly without compromising safety standards.

The study and practical implementation yielded results that demonstrated that work efficiency within time constraints could be achieved as per the study's objectives. This aligns with the research conducted by Thanadol et al. (2023) on streamlining the document handling process for inbound cargo clearance using lean principles: a case study of XYZ Company.

8.2.2. To enhance the efficiency of operations on M.T. Tsurusaki and practice environmentally friendly procedures, standards for environmental maintenance must be complied with in addition to the development and enhancement of work procedures. Preventing oil spills overboard is crucial, as occupational pollution can negatively impact the company's costs related to various operational expenses and pollution control costs.

From studies and practical implementation, it can be used to identify the primary causes of the problem and assess viable fixes by the research's conclusions. Using the lean approach could be beneficial in minimizing the work processes., aligning with the objectives set in the study, and matching the research of Thanadol et al. (2023) on streamlining the document handling process for inbound cargo clearance using lean principles: a case study of XYZ Company.

8.3. To enhance the efficiency of operations on M.T. Tsurusaki in terms of reducing costs and time in conducting tasks.

It is crucial to minimize downtime. The ship cannot generate income for its owner when it is not receiving cargo, and conversely, it incurs expenses continuously. Therefore, if the ship spends the least amount of time waiting, it translates into reduced waiting costs. Improving the efficiency of tank cleaning operations plays a significant role in reducing operational expenses.

Efficient management of the tanker's cleaning process can reduce wait times, as per the study and its practical implementation. In addition to decreasing expenses, this waiting time reduction improves overall operational management. Reducing waiting times can save an extensive amount of cost, aligning with the study's objectives and in line with the research conducted by Tippawan (2016) on enhancing efficiency in managing commercial fleets.

Before the changes, the work process will focus on following the company's procedures, emphasizing workplace safety, and minimizing the chances of generating pollutants or oil spills. However, it takes a relatively long time to complete the work,

leading to higher costs.

After changes resulting from a group discussion, the work standards for safety remain the same, ensuring a safe working environment without pollution or oil spills. Oil contamination is avoided as much as possible, and the time and expense of the task have been decreased.

This study shows that it is possible to decrease working hours, minimize expenses, and improve the safety of workers by implementing the concepts and understanding gathered from both lean systems and pertinent research. It makes complicated work procedures simple for workers to comprehend.

9. Recommendation

9.1 Recommendations for implementing

1) The M.T. Tsurusaki crew members maintain the ship well, to ensure it is constantly in working order. As a result, there are no problems resulting from malfunctioning equipment or machinery during normal operations. However, if there is a lack of attention to the maintenance of machinery and equipment, problems can arise in the workflow, leading to delays and potential future consequences.

2) Adapting equipment or the increasing quantity of equipment on the vessel can significantly enhance operational efficiency.

9.2 Future research direction

1) It is advisable to study the availability of dry docks in each ASEAN region and determine the distance from the Thai ports to the dry docks. This will allow for calculating travel times and preparing the necessary resources for operations.

2) Utilize knowledge and skills to advance the expertise of Thai crews, making them competitive on a global level, similar to crews from countries recognized worldwide. If Thailand can develop this industry with skilled Thai seafarers, it has the opportunity to compete in the future by promoting and supporting businesses in this sector.

3) Research should be conducted on each type of crude oil to determine if they have similar tank cleaning processes, as there are several types of crude oil. Additionally, different equipment and installation positions should be considered to achieve the highest efficiency in tank cleaning.

เอกสารอ้างอิง

Aydin, M., Arici, S. S., Akyuz, E., & Arslan, O. (2021). A probabilistic risk assessment for asphyxiation during gas inerting process in chemical tanker ship. *Process Safety and Environmental Protection, 155,* 532-542.

Dock, A., Linders, J., David, M., Gollasch, S., & David, J. (2019). Is human health sufficiently protected from chemicals discharged with treated ballast water from vessels worldwide?–A decadal perspective and risk assessment. *Chemosphere*, *235*, 194-204.

Fakher, S., Ahdaya, M., Elturki, M., & Imqam, A. (2020). Critical review of asphaltene properties and factors impacting its stability in crude oil. *Journal of Petroleum Exploration and Production Technology*, *10*, 1183-1200.

Jurairat, W., & Chitpong, A., (2019). Management of Rail Transport Efficiency: A Case Study of Bangkok-Chiang Mai Route, *Social Science Journal of Prachachuen Research Network: SSJPRN. 1*(2), 52-63.

Maljković, M., Vukša, S., Vidan, P., & Pavić, I. (2022). Review of Cargo Operations on Crude Oil Tankers and Methods/Models Used for Optimisation and Improvement of Safety. *Časopis Pomorskog fakulteta Kotor-Journal of Maritime Sciences*, *23*(1/2022), 153-164.

Mislav. M., Srđan. V., Pero. V., & Ivica P. (2022). Review of Cargo Operations on Crude Oil Tankers and Methods/Models Used for Optimisation and Improvement of Safety, *Journal of Maritime Sciences(JMS), 23*(1), 153-164.

Muhammet. A., Seher, S., Emre, A., & Ozcan, A., (2021). A Probability risk assessment for Asphyxiation During gas inerting process in chemical tanker ship. *Process Safety and Environmental Protection, 115,* 532-542.

Nuchayar. (2023). *Fuel consumption in eight months of 2023 (Jan-Aug)*. Retrieved 29 September 2023. From: https://www.electricityandindustry.com/situation-of-oil-use/.

Siddiqui, A., Verma, M., & Verter, V. (2018). An integrated framework for inventory management and transportation of refined petroleum products: Pipeline or marine?. *Applied Mathematical Modelling, 55*, 224-247.

Strategy and Planning Division, Department of Energy Business. (2015). *Fuel Oil Refinery Business in Thailand. Department of Energy Business. Ministry of Energy*, Thailand

Sulaiaman, R., Mohamed, A., & Konstantinos, S. (2022). Using Industry 4.0 Capabilities for Identifying and Eliminating Lean Wastes, *Procedia CIRP, 107,* 21-27.

Thanadon P., Natthachai W., Phaithun H., & Navan S (2023) Modification Process and Paperwork Reduction by Using Lean for Efficiency Improvement and Customer Satisfaction. *The 9th National Conference on Technology and Innovation Management NCTIM 2023*, 9 March 2023. Rajabhat Maha Sarakham University, Maha Sarakham, Thailand. 1248-1256.

Thantawan, P., Piyakorn, S., Chanphen, P., & Wanpichit, B. (2020*). Blocked Bricks Production Waste Reducing, Case Study: Kamphu Construction Materials Store*. Retrieved 9 August 2023, From: https://www.khonkaen.spu.ac.th/spu/wp-content/uploads/2020/03/การลดความสูญเปล่ากระบวนการผลิตอิฐบล็อก-กรณีศึกษาร้านคำพุก่อสร้าง.pdf.

Tippawan, S. (2016). *Increasing the Efficiency in Merchant Fleet Management*. Thesis of the Degree of Master of Logistics and Supply Chain Management, Burapha University.

Yaw, Agyabeng-Mensah., Liang, T., Ebenezer, A., Charles, B., & Essel, D. (2021). Organisational Identity and Circular Economy: Are Inter and Intra Organisational Learning, Lean Management and Zero Waste Practices Worth Pursuing?, *Sustainable Production and Consumption, 28,* 648-662.