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Enhancing inbound logistics in the tuna canning industry through simulation: A case analysis

Woraya Neungmatcha[1)], Atiwat Boonmee*[1)] and Ampika Boonmee[2)]

[1)]Department of Industrial Engineering, Faculty of Engineering at Kamphaeng Saen, Kasetsart University, Nakon Pathom 73140, Thailand
[2)]Department of Basic Science and Physical Education, Faculty of Science at Si Racha, Kasetsart University, Chon Buri 20230, Thailand

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Abstract

This research proposes an enhancement strategy for inbound logistics planning in the canned tuna industry, focusing on raw material transportation. Currently, the company experiences a 164-day shortfall (67% of total receiving days) in planned versus received raw materials. Using eight trucks, the company achieves an average of 16 daily cycles with a truck utility of 45.58%. Notably, the average pre-dumping fish temperature is -17.19°C, and delivery time is 7.2021 hours. Through simulation analysis, four problem-solving strategies are proposed. One scenario suggests reducing the fleet from eight to six trucks, increasing truck usage utility to 57.91% and reducing driver hiring costs by 25% to 1,440,000 baht per year. Furthermore, delivery time improves by 20.06% to 5.7574 hours. This research offers a strategic approach to optimize inbound logistics, improving efficiency and reducing costs.

Keywords: Inbound logistics management, Tuna canned industry, Simulation

1. Introduction

The seafood processing industry plays a significant role in Thailand's economic development, positioning the country as a potential global leader in competitive and reliable seafood production. The company under study is a well-known seafood exporter, with a strong market presence in North America, Europe, Asia, and the Pacific. In 2021, their processed seafood sales reached 58,955 million baht, accounting for 42% of total sales, primarily driven by tuna products [1]. However, the industry currently faces challenges associated with high production costs. Most of the raw materials used are imported, where the price of raw materials in each period is quite volatile. The price of raw materials will follow the mechanism of the price of agricultural products that fluctuates with the season and there is uncertainty in the quantity of produce according to the weather. Procurement of raw materials or tuna requires seasonal purchases in large lots and then cold storage to ensure that there will be enough raw materials to meet demand throughout the year. The above reasons make logistics management costs both raw material procurement costs and storage costs high. In addition, due to the purchase of large quantities, raw materials must be transported from the port to be stored in the company's cold storage as quickly as possible. Efficient raw material transportation management will help save costs and preserve the quality of the fish to remain as fresh as possible, which is important for further processing. Therefore, efficient management of logistics activities within the supply chain is crucial for delivering high-quality products at competitive prices. Inbound logistics involves the use of tuna for production, and any delays in this process can lead to increased fish temperatures and a subsequent decline in the quality of raw materials used for processing. Figure 1 shows that the average fish temperature starting from the freezer on the ship is -24.73°C, then the fish loaders at the port will transfer the fish from the cold room to the net and then use a crane to move into the truck. The average temperature of the fish during transportation from the port until the sorting process at the company before storage is -16.96°C. But if there is inefficient transportation cycle management, the temperature of the fish from the port to the separation process will increase, resulting in the frozen fish separating and partially thawing. Therefore, during sorting it may damage the raw material and especially when re-frozen in the company's cold storage, the fish skin will stick together. When there is an order from a customer and the fish must be sorted to be passed on to the production department, it will be difficult to sort and affect the quality of raw materials accordingly. These factors highlight the significance of optimizing the inbound logistics process to ensure efficient and timely delivery of quality seafood products. A crucial bottleneck impeding overall productivity pertains to the transportation of tuna from the port to the processing plant. This operation entails the collection of tuna from the port by trucks and its subsequent delivery to a cold storage warehouse. Additional sub-processes such as import documentation lack systematic planning, resulting in inefficiencies, unnecessary waiting periods, and resource misuse.

*Corresponding author.
Email address: atiwat.bo@ku.th
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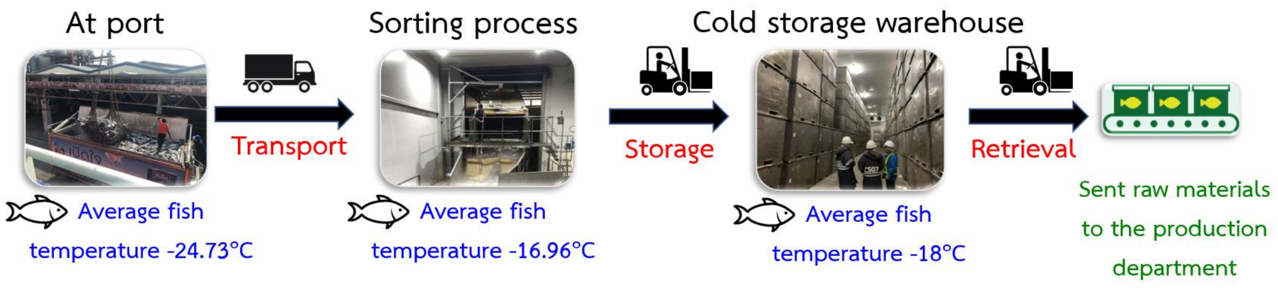


Figure 1 Schematic representation of the case study company's inbound logistics system

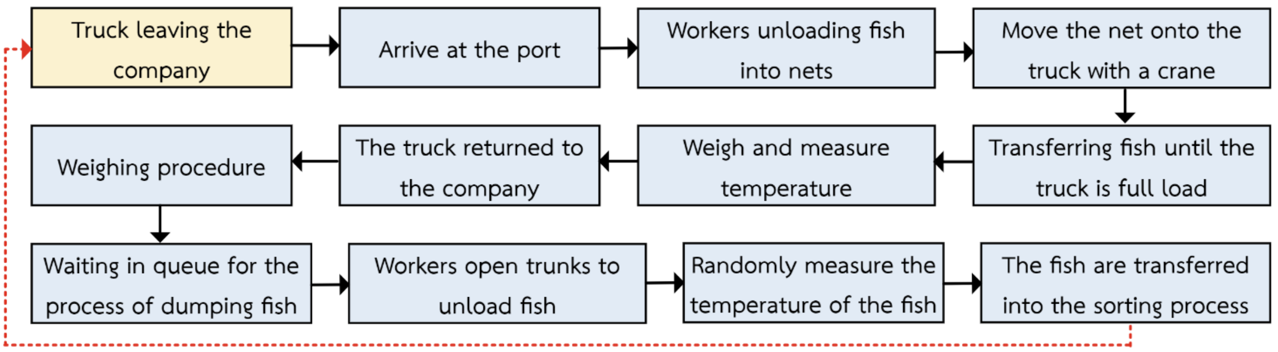


Figure 2 Transportation operations within the case study company's inbound logistics system

Figure 2 demonstrates the company's transportation operations. An analysis of the company's port fish receiving volume data revealed that the actual number of raw material receipt days fell short of the planned amount by up to 164 days, accounting for 67% of total planned receiving days. Examination of the current conditions divulged significant delays within the system: trucks were idle for an average of 180 minutes before the loading process and a further 59 minutes before initiating the dumping process for species and size sorting. These holdups form a significant portion of the lead time within the system, causing a low truck utilization rate. Furthermore, post-loading, an average delay of 144.62 minutes was observed before the onset of the fish dumping process for species and size categorization. Consequently, the average fish temperature rose by 7.77°C, equivalent to an average hourly increase of 3.22°C. This study endeavors to identify strategies to mitigate these inefficiencies and enhance operational productivity. The primary objective of this study was to devise an efficient management strategy for the transportation process within the inbound logistics system, aiming to optimize the number of daily fish-dumping cycles and the appropriate utilization of trucks. Key indicators considered for these purposes included average truck utility, fish quality retention, and average delivery cycle times, the latter forming one of the logistics efficiency indicators for Thailand's industrial sector (ILPI8T) [2]. The implementation of simulation models was considered to facilitate a comprehensive analysis of the company's transport process, providing insight into the interrelationships among subsystems within a larger, complex system. Simulation techniques have become increasingly popular in the fields of production planning and logistics management due to their distinct advantages in enabling informed decision-making processes. Simulation allows for the analysis of intricate systems that would otherwise be difficult to dissect and understand. It provides the ability to model and study complex interactions, dependencies, and processes, which may not be immediately apparent. Although creating a simulation may involve some initial costs, the ability to test various scenarios without interrupting actual production processes can lead to significant long-term cost savings. Simulation models can be easily modified to adapt to changing conditions, new data, or revised business strategies. This makes them a flexible tool that can evolve with a company's needs. A review of existing literature revealed the widespread application of simulation techniques across diverse research areas. These areas span production systems [3-5], warehouse management [6, 7], layout selection [8, 9], service system management [10], water distribution networks [11], and resource management within logistics systems [12-14], among others. Simulation techniques are a valuable tool for optimizing production planning and logistics management, as they can identify bottlenecks, streamline processes, and improve resource allocation. Through this study, we hope to contribute to this body of knowledge, providing practical solutions for enhancing logistics efficiency in the seafood processing industry.

2. Methodology

The research process of simulation model consists of the following 6 steps:

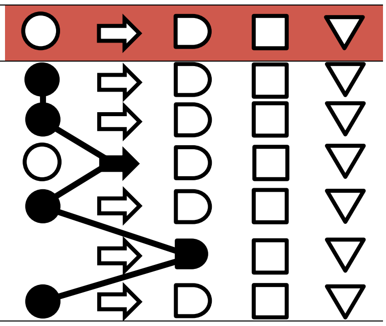
Step 1 Problem definition:

A detailed flowchart depicting the current state of the company's inbound raw material transportation is presented in Table 1.

An analysis of the data regarding fish reception at the port, spanning 246 days, revealed a shortfall in raw material reception. On 164 days, or 67% of the total days, the company received less raw material than planned. The principal reasons for this shortfall can be traced to two main factors: 1) The labor-intensive and time-consuming process of loading fish onto each truck, causing a failure to meet the company's planned truck loading schedule; and 2) The discrepancy in the total weight of the fish received, even when the planned number of transport queues was fulfilled. The latter issue was due to the large size of the fish creating gaps within the truck. Currently, the company employs eight trucks operating in sequential rotation for fish pick-up from the port. Two additional trucks have been procured but are yet to be commissioned. The first and second trucks designated for raw material reception are scheduled to depart from the company at 5:30 a.m., while trucks number 3 to 8 commence their journey at 7:30 a.m. The port operates from 8:00 a.m. to 12:00 a.m.

Table 1 Flow chart depicting the current inbound raw material transportation process

No	Detail	Time (Min.)
1	Fish loading onto trucks	45
2	Moving the truck from the fish loading point to the weighing point	5
3	Truck's return to the company	81
4	The truck and the fish carried are weighed together at the weighing station and then the fish are dumped at the fish dumping point.	5
5	Queueing for the sizing and separating process	59
6	The fish are transported to the sorting process	43
	Total	238



Step 2 Data collection:

1) Primary data were procured through observational studies and interviews conducted with workers involved in the case study. This set of data encapsulates the methods or procedural routines of employees at each stage of production and the corresponding operational timeframes. For the sake of robustness in subsequent analytical procedures, time data at each stage was collected across a minimum of 30 iterations.

2) Secondary data were gleaned from a variety of company production reports spanning a one-year period. These data sets included the daily port pick-up schedules, which elucidate the case study company's planning strategies regarding daily fish collection, along with information pertaining to the time allocated for each operational activity.

Step 3 Model building:

1) Firstly, assumptions for the computer modelling were established.

2) Subsequently, utilizing all gathered data and the aforementioned modelling assumptions, a computer simulation was constructed using the Arena software. This simulation aimed to replicate the workflow of the case study company (Figure 3).

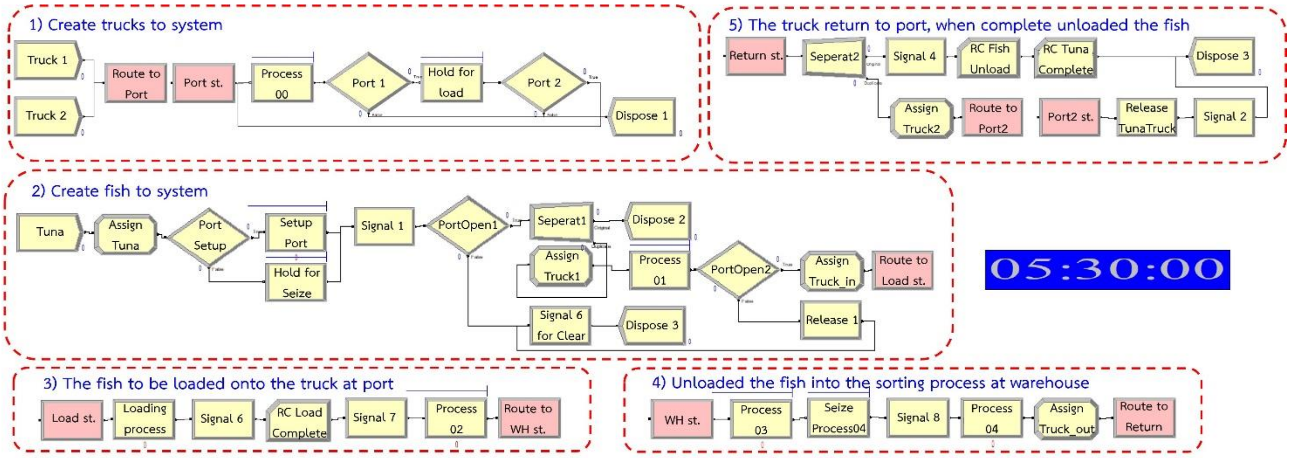


Figure 3 Arena-based simulation model of the case study's existing process

The author utilized the input analyzer within the Arena software to assess the distribution of data across all processes (time unit: minutes). This analysis subsequently facilitated the construction of a comprehensive process flow diagram, as delineated in Figure 4. Simulation models require processes that are virtually identical to actual system processes, such as raw material flow and truck flow, the work of staff loading raw materials or the working time of the whole system, etc. The results of the distribution analysis were used in a model created using an arena computer program in which 50 reprocessing cycles were defined.

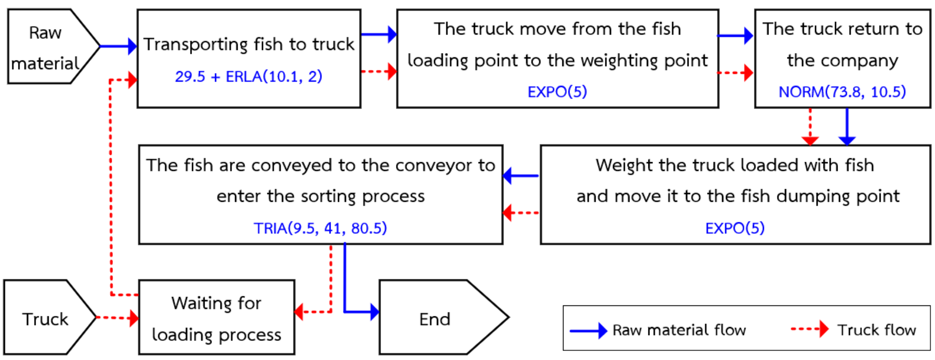


Figure 4 Schematic diagram of systematic process flow

Step 4 Model verification and validation:

1) Model verification: Simulation models necessitate a near-perfect mimicry of actual system processes. This includes the flow of raw materials and trucks, staff operations in loading raw materials, and the overall system functioning time, among others. The outcomes derived from the distribution analysis were incorporated into a model developed using the Arena software, and the model was configured to execute 50 reiteration cycles.

2) Model validation: Initially, we must outline various pieces of information required for the configuration of the run setup. The system initiates operations at 5:30 a.m., and raw materials can be loaded onto the trucks following the opening of the port from 8:30 a.m. to 12:00 a.m. The length of each replication cycle is set to 24 hours. The model's suitability was validated using two criteria: 1) The average time for each truck from the onset of the picking process to the completion of the dumping, which was found to be 237.956 minutes or 3.9659 hours based on actual data, and 2) The average waiting time for each truck to dump, which was found to be 58.648 minutes, or 0.9775 hours based on actual data. Upon conducting a simulation of 50 cycles, it was found that the average time of each truck in the system was 4.0455 hours, and the average waiting time for each truck to dump was 0.9433 hours. The statistical analysis carried out with SPSS revealed that the Sig. (2-tailed) values were 0.359 and 0.693, respectively, each exceeding 0.05 (refer to Table 2). Therefore, it is inferred that this model can adequately serve as a proxy for the real-world system.

Table 2 Comparative analysis of simulation model data and real-world observations

Data Validation	Actual system value (hr.)	Value from model (hr.)	Sig. (2-tailed)	Result
Average time in system of each truck	3.9659	4.0455	0.359	Pass
Average waiting time for dumping of each truck	0.9775	0.9433	0.693	Pass

Step 5 Propose a process improvement approach:

From Table 1, it can be seen that the process of transporting raw materials or fish found that Activity 3 traveling from the port to the factory warehouse was the most time-consuming activity. In the analysis of the situation with the simulation model, it was found that activities that caused high waiting time were Activity 1, conveying raw materials into trucks and Activity 6, conveying raw materials onto the conveyor belt to enter the process of sorting fish sizes and species. A strategic framework for enhancing processes has been proposed with the aim of optimizing the company's inbound logistics management. Scenario modeling serves as a valuable tool for exploring potential alternatives prior to implementation can be concluded in Table 3.

Table 3 Wastes and causes to analyze solutions.

Wastes	Causes	Solutions
1. The loss of transportation from the port to the company took a long time.	Traffic on the road.	- Due to the inevitable traffic on the road and the main route to enter the port, there is only one route. Therefore, in discussion with the case study company, it is desirable to study the appropriateness of the number of trucks to transport raw materials as the **Scenario 1**. In addition, the company has a plan to try a trailer truck, so it would like to study the appropriateness of the possible number of tractors as a **Scenario 2**.
2. Wasting time waiting for raw materials to be loaded onto trucks	Waiting for the previous truck to finish loading the material due to the delay in the loading process at the port.	- This is because the process of loading fish onto trucks at the port is a bottleneck. Therefore, an analysis of whether the operation at the port can improve more efficiently will affect the number of cycles of trucks that complete the fish per day as a **Scenario 3**.
3. Waiting for the turn of the truck loaded with fish to the weighing station at the port.	The layout and traffic direction at the port are not good.	
4. Time wasted waiting for raw materials to be transported to the sorting conveyor at the company.	Waiting for the previous truck to finish loading the raw materials into the sorting conveyor due to the delay in the unloading process at the company.	- This is because the sizing and sorting process is a process with a high lead time that affects the quality of the fish. Therefore, analyzing how if the company's warehouse can improve such processes to be more efficient will affect the efficiency of the raw material flow of the system is the **Scenario 4**.

Step 6 Evaluating the efficacy of each proposed scenario:

The authors evaluated the effectiveness of each approach using five key performance indicators: 1) daily completed fish dumping cycles, 2) number of trucks utilized, 3) average truck utility, 4) fish temperature retention, and 5) average delivery time, otherwise referred to as ILPI8T.

3. Results and discussion

Currently, the company maintains a fleet of eight trucks dedicated to the transportation of fish from the port to its warehouse. Under the existing system, it is found that there are various variables in the current situation that will be analyzed as follows:

1) The average delivery cycle time, denoted as ILPI8T, comprises the time spent in truck queuing before picking up (3.1566 hours) and the duration of fish pick-up and dumping (4.0455 hours), resulting in a total of 7.2021 hours.

2) The schedule utilization of each truck ranged from 37.94% to 48.13%, with an average of 45.58%. The average utility of fish loading workers at the port was 86.45%. The sizing and separating process exhibited an average utility of 75.84%.

3) Model results identified bottlenecks in the truck loading process. This stage recorded the highest average waiting time of 3.1566 hours, accounting for 74.13% of the total waiting time. The waiting time for trucks prior to dumping ranked second, with an average

of 0.9433 hours, constituting 22.15% of the total waiting time. The average time taken after fish loading at the port, until the trucks returned to the company's warehouse and completed the unloading process, was approximately 2.3385 hours on average.

4) The port operates its truck loading services until 12:00 a.m. On average, the number of completed dumping cycles per day ranged from 14 to 19 cycles, with an average of 16 cycles per day. The average quantity of raw materials transported into the sizing and separating process amounts to 288 tons, considering that each truck has an average capacity of 18 tons of fish.

5) Prior to dumping, the average temperature of the fish was -17.19°C.

For the solution presented in Section 2, Step 5, the results of the simulation analysis for each scenario can be summarized as follows.

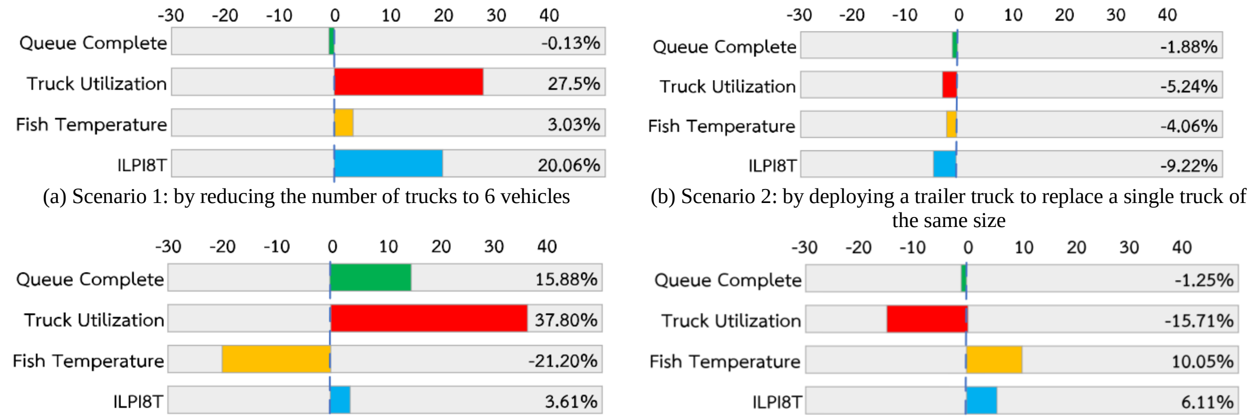
Scenario 1: The author conducted adjustments to the number of trucks, varying them from 8 to 9 and 10, as well as reducing them to 7, 6, and 5. Simulation results indicated that increasing the number of trucks from 8 to 9 and 10 resulted in a marginal increment of 0.6% and 0.5%, respectively, in the number of completed dumping cycles per day. However, this led to a reduction in average truck utility and an increase in process wait times. Conversely, reducing the number of trucks from 8 to 7 and 6 resulted in a slight decrease of 0.1% in the number of completed dumping cycles per day. Further reduction to 5 trucks decreased the number of completed dumping cycles by 1.08 cycles per day, equivalent to a 6.75% reduction.

Diminishing the number of trucks involved in fish deliveries enhanced average truck utility and reduced lead times for each process. Moreover, it reduced the time interval between fish loading onto the truck and the dumping process at the company. Consequently, this reduction in processing time prevented any increase in fish temperature. Currently, the cost of employing drivers for 8 trucks amounts to 1,920,000 baht per year (calculated based on a monthly driver wage of 20,000 baht). Thus, reducing the number of trucks to 6 would result in a reduction of 2 drivers, reducing costs by 480,000 baht per year, or 25% from the original expense. Additionally, the reduced time between fish loading and dumping at the company averaged at 9.7 minutes. This approach facilitated the maintenance of an average fish temperature of 0.52°C. Furthermore, the average delivery time, or ILPI8T, was reduced by 1.44 hours.

Scenario 2: The author explored the simulation of incorporating trailer trucks as an alternative to increase the raw material capacity to twice the original amount. This approach involved introducing 1, 2, and 3 trailer trucks to replace the existing trucks. The simulation results revealed that transitioning to trailer trucks did not yield an increase in the number of completed dumping cycles per day. Furthermore, the overall utility of the trucks was lower than the average, and the waiting time for each process experienced an increase. Consequently, it can be concluded that the utilization of trailer trucks as a replacement for traditional trucks in raw material transportation is not deemed appropriate based on these findings.

Scenario 3: The authors conducted an analysis to determine if the efficiency of the truck loading process at the port could be improved, either by employing more labor or utilizing more efficient loading and unloading aids. Through simulation modeling, various levels of efficiency enhancement were considered, ranging from 5% to 30%. The simulation results revealed that optimizing the truck loading process would lead to a substantial increase in the number of completed fish dumping cycles per day, ranging from 1.6% to 15.9%. The waiting time at the port experienced a significant reduction. However, when the efficiency was increased from 20% to 25% or 30%, there was a slight rise in the number of dumping cycles, reaching the maximum capacity limit of the sizing and straining process. Notably, with a 30% increase in the efficiency of the truck loading process at the port, the average fish loading time until the start of dumping increased to 6.1-87.8 minutes, resulting in a rise in the average fish temperature by 4.72°C. Hence, it is recommended that the company engages in discussions with suppliers to enhance the efficiency of raw material loading at the port, as it can increase the number of fish transport cycles but may elevate the fish temperature. The 25% increase in the efficiency of this process reduced the average delivery time, or ILPI8T, by 0.26 hours.

Scenario 4: The authors conducted an analysis of cases where companies optimized the sizing and separating processes by employing auxiliary devices or optimizing the process layout to enhance efficiency. Simulation modeling was performed to evaluate scenarios with efficiency improvements of 5%, 10%, 15%, 20%, 25%, and 30% in this process. The simulation results indicated that enhancing the efficiency of the dumping process did not lead to a significant increase in the number of truck cycles completing fish dumping per day. This is attributed to the process not being a bottleneck within the system. However, it considerably reduced the average waiting time at the company warehouse and significantly decreased the process time from fish loading on the truck to the start of dumping, ranging from 5.9 to 32.2 minutes. Consequently, this approach maintained an average fish temperature of 1.73°C. Although the efficiency improvement did not directly impact the number of fish transport cycles, it effectively mitigated temperature rise prior to the sizing and separating process. Moreover, it reduced the refrigeration load at the cold storage warehouse and decreased the mean delivery time of ILPI8T by 0.44 hours. An overview of the results from all four scenario experiments is presented in Figure 5 and Table 4.



(a) Scenario 1: by reducing the number of trucks to 6 vehicles

(b) Scenario 2: by deploying a trailer truck to replace a single truck of the same size

(c) Scenario 3: by enhancing the efficiency of the fish loading process by 25%

(d) Scenario 4: in the efficiency of the sizing and separation process with a 30% enhancement approach

Figure 5 Percentage improvement achieved by each scenarios

Table 4 The results of all four scenario experiments

Situation	The total dump truck cycles per day	Number of trucks	Average truck utility (%)	Pre-dumping fish temperature (°C)	ILPI8T (hour)
Current Situation	**16.00**	**8**	**45.58**	**-17.19**	**7.2021**
9 trucks	16.10	9	41.00	-17.20	7.8294
10 trucks	16.08	10	38.52	-16.62	8.5597
7 trucks	15.98	7	50.98	-17.40	6.5214
6 trucks	**15.98**	**6**	**57.91**	**-17.71**	**5.7574**
5 trucks	14.92	5	62.66	-18.22	5.4381
1 trailer	15.70	8	43.19	-16.49	7.8659
2 trailers	15.98	8	39.8	-16.48	8.0488
3 trailers	15.90	8	35.94	-17.26	8.3301
Loading fish onto the truck is 5% faster	16.26	8	47.18	-16.86	7.1608
10%	16.98	8	51.06	-16.03	7.1244
15%	17.32	8	54.28	-15.20	7.0843
20%	18.20	8	59.72	-14.17	6.9557
25%	**18.54**	**8**	**62.81**	**-13.55**	**6.9420**
30%	18.36	8	65.58	-12.47	7.1442
Dumping fish 5% faster	16.06	8	44.53	-17.51	7.1141
10%	15.92	8	42.87	-17.85	7.0654
15%	16.12	8	41.39	-18.51	6.8100
20%	16.04	8	40.99	-18.42	6.8465
25%	15.96	8	39.83	-18.67	6.7475
30%	**15.80**	**8**	**38.42**	**-18.92**	**6.7619**

Note: The average temperature of fish after loading the fish at the port was -24.73°C

As shown in Table 4, it can be seen that the most effective scenario for maximizing the number of transport cycles and maintaining the fish temperature is to use 6 trucks and try to improve the efficiency of fish loading at the port by 25%, as well as trying to improve the efficiency of fish unloading at the company by 30% faster. In addition, further analysis for some combinations of significant scenarios could be performed to provide more insightful results, as summarized in Table 5.

Table 5 The analysis for some combinations of significant scenarios

Number of trucks	% Loading fish onto the truck process faster	% Dumping fish process faster	The total dump truck cycles per day	Average truck utility (%)	Pre-dumping fish temperature (°C)	ILPI8T (hour)
6	**25**	**30**	**17.520**	**0.5603**	**-18.70**	**5.0311**
6	30	30	17.380	0.557	-18.63	5.024
6	20	30	17.280	0.5486	-18.87	5.0040
6	15	30	16.800	0.5359	-18.83	5.1153
6	10	30	16.720	0.5287	-19.01	5.0434
6	5	30	16.440	0.5200	-19.06	5.1576
6	25	25	17.340	0.5755	-18.27	5.1595
6	25	20	17.240	0.5805	-18.20	5.2371
6	25	15	16.940	0.5901	-17.77	5.3972
6	25	10	16.980	0.6074	-17.44	5.4843
6	25	5	16.620	0.6258	-16.75	5.7215
6	25	35	17.460	0.5441	-18.96	4.9008
6	25	40	17.440	0.5355	-19.04	4.9148
6	25	45	17.600	0.5277	-19.25	4.7768
6	25	50	17.640	0.5193	-19.35	4.7280
6	25	55	17.740	0.5167	-19.39	4.6626

When experimenting with setting the fish unloading capacity at the company constant at a 30% faster efficiency and varying the fish loading efficiency at the port, it was found that setting the fish loading efficiency more would result in the total dump truck cycles per day and other parameters to be measured are similar to the best scenario from the four alternatives listed in Table 4. But if the % Loading fish onto the truck process was reduced, the total dump truck cycles per day would decrease significantly, indicating a clear bottleneck of the fish loading process at the port. Therefore, the company should come up with an urgent approach in consultation with the port to improve the process of fish loading at the port in various activities to be more efficient. In addition, if we experiment with setting the "% Loading fish onto the truck process faster" constant and varying the "% Dumping fish process faster" value to decrease, it will result in the total dump truck cycles per day being clearly reduced. This is because the bottleneck will be in the fish dumping activities where the company is unable to recirculate trucks to pick up more fish. Finally, if we experiment with varying the "% Dumping fish process faster" value further, it is found that it will not affect the total dump truck cycles per day much more due to the limitations of the ability to work at the loading fish process and full working time available in one day.

4. Conclusion

Currently, the average truck utilization is relatively low (45.58%). In Scenario 1, the company can reduce the number of trucks from 8 to 6 without impacting the number of completed dumping cycles per day. This optimization increases the average truck utilization to 57.91%, resulting in a 25% reduction in driver hiring costs from 1,920,000 baht per year to 1,440,000 baht per year. Additionally, the average delivery time (ILPI8T) is reduced from 7.2021 hours to 5.7574 hours, representing a 20.06% decrease. The simulation highlights the loading process at the port as a bottleneck, and addressing this can be delegated to the supplier for labor arrangements. Furthermore, enhancing the efficiency of the fish loading process at the port by 5% to 30% significantly increases the number of completed fish loading cycles per day (1.6% to 15.9% increase). However, these improvements impact the average delivery time (ILPI8T) and result in higher average fish temperatures. Another crucial process is the sizing and separating process. Enhancing the efficiency of the dumping process by 30% reduces wait times during fish sorting and maintains an average fish temperature of 1.73°C. The average delivery time (ILPI8T) decreases by 0.44 hours or 6.11%. Conversely, the adoption of trailer trucks does not contribute to increased daily fish transport cycles and leads to longer waiting times in the processes. Therefore, these simulation-based scenarios provide valuable insights for the company to analyze the current situation and identify suitable alternatives before implementing them in practice.

5. Acknowledgements

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