APPLICATIONS OF LEAN PRINCIPLES AND OPERATIONS RESEARCH MODELS IN FISH PORT OPERATIONS

Paul Michael S. Pudan*, Dane G. Delima, Michelle Jeigh G. Gulabrai, Noriel S. Cabutaje, Anne N. Natividad
Bachelor of Science in Industrial Engineering
College of Engineering
Occidental Mindoro State University
**paulmichaelpudan@gmail.com*

ABSTRACT

Fish ports function as critical infrastructure in maritime logistics; however, their performance is frequently hindered by non-linear delays and unoptimized resource management. This research employs a systemic Industrial Engineering (IE) framework to enhance the operational throughput of the Caminawit Fish Port. Utilizing Value Stream Mapping and Pareto Analysis, the study identified that 70% of systemic inefficiencies are rooted in "Methods" and "Manpower" rather than physical capacity constraints. A one-way ANOVA confirmed a statistically significant divergence in bottleneck perception among personnel ($p = 0.0024$), validating the absence of a standardized operational protocol. To engineer a mathematically validated solution, the study utilized Linear Programming, specifically the Simplex and Big M algorithms, to model an optimal state for the facility. The results demonstrate that adopting a Lean-optimized "Cycle 6" satisfies the mandatory 24-ton monthly demand while reducing total process time from 8 hours to a minimized 8,712 seconds, effectively unlocking a 70% increase in operational efficiency. The model further identified labor as the binding constraint, achieving a maximum objective value of Z (Profit) = 320 units through strategic task reallocation. This research concludes that the integration of IE optimization tools is indispensable for transforming traditional maritime facilities into high-performance logistics hubs, providing a scalable blueprint for regional infrastructure management without the necessity for capital-intensive expansion.

Keywords: *industrial engineering, linear programming, operations research, post-harvest loss, value stream mapping*

SDG: *SDG 2 - Zero Hunger, SDG 8 - Decent Work and Economic Growth, SDG 9 - Industry, Innovation, and Infrastructure, SDG 12 - Responsible Consumption and Production, SDG 14 - Life Below Water*

INTRODUCTION

Fishing ports serve as critical logistical hubs, integrating infrastructure, human resources, and management to facilitate efficient fleet operations (Smith et al., 2020). These ports act as strategic anchor points for landing, processing, and distributing catches, while simultaneously fostering the economic development of coastal communities (Hutapea et al., 2017; Suadi & Kusano, 2019). In the Philippines, Occidental Mindoro plays a vital role in the MIMAROPA fishery sector, producing approximately 21,898 metric tons in 2023 and accounting for 4.9% of the regional output (Philippine Statistics Authority, 2024). Despite this high productivity, the industry faces a downward trend in wild-catch volume, making the operational efficiency of primary hubs like the Caminawit Fish Port in San Jose essential for sustaining local livelihoods and domestic food security (Bureau of Fisheries and Aquatic Resources, 2023; Department of Trade and Industry MIMAROPA, 2023).

Previous research has increasingly emphasized the transformative power of Lean principles in maritime and logistics environments to eliminate waste and maximize value-added outcomes (Santoso et al., 2025). Studies of port terminals in Taiwan and Brazil have demonstrated that Lean management significantly improves efficiency by minimizing idle periods and optimizing workflow without requiring heavy capital investment (Bonamigo et al., 2023; Kuo & Lin, 2020). Similarly, Operations Research (OR) methods, such as linear programming, have been widely applied for resource allocation and berth scheduling (Arani et al., 2021; Zhai et al., 2022).

However, a crucial research gap exists; few studies have developed an integrated Lean-OR system specifically tailored to the unique characteristics of fish ports, such as product perishability, cold-chain synchronization, and the specific labor roles of sorters, ice loaders, and fish loaders (Food and Agriculture Organization, 2020). In the Philippine context, post-harvest losses are estimated between 25% and 40% due to mishandling and port inefficiencies, yet the combined application of Lean and OR remains limited (Baclig, 2023; Souaini et al., 2026). The purpose of this study is to address this gap by creating and testing an integrated Lean-OR model at the Caminawit Fish Port to enhance operational management, reduce spoilage, and achieve supply chain sustainability.

The study sought to identify operational inefficiencies at fish ports by root cause analysis, employing Ishikawa diagrams, Pareto analysis, and trend analysis. Consequently, upon identifying the core causes of the operation, the use of lean principles and operations research models were employed to establish a framework for enhancement, potentially resulting in optimized and effective supply chain management. Therefore, the objective of this study was to minimize operational inefficiencies and boost operational productivity.

METHODS

Research Design

The process began with Problem Identification, where researchers conducted end-to-end site observations to identify baseline inefficiencies and operational bottlenecks within the current workflow. This was followed by the Data Gathering phase which identified manual labor as primary driver of inefficiency, allowing the researchers to apply Lean principles to isolate and optimize bottlenecks from unloading to final loading. Consequently, the framework transitioned into the Development of Models. By integrating Value Stream Mapping (VSM) and Operations Research (OR), the analysis qualitatively identifies process waste and utilizes the Simplex Algorithm to mathematically optimize labor and capacity for maximum operational value. The framework concludes with the interpretation of results and an assessment of the model's effectiveness, fostering data-driven insights for further optimization of the fish port management system.

Participants of the Study

The stratified random sampling method is employed to ensure accurate representation of all worker categories at each stage. The strategy categorized the fish port staff into suitable subcategories, including operators, fishermen, and ice and fish loaders. There were 304 participants who participated in the study to provide a balanced representation of opinions among four fishing processes. The researchers categorized the population into subgroups based on port location to ensure proportional representation across all operational segments from unloading to final loading by utilizing stratified sampling with 304 samples. This profitability method reduces sampling bias and ensures that results are statistically generalizable for optimizing process efficiency and resource allocation.

Data Collection

An integrated framework of ishikawa, pareto and trend analysis was used to conduct a thorough root cause analysis (RCA) to identify systemic inefficiencies and process non-conformance. The "6ms" framework, which includes manpower, methods, machines, materials, measurement and mother nature, was used to systematically classify the factors that create delayed throughput and idle time. The cumulative percentages were calculated for each of these categories and a pareto chart was created to identify the "vital few" root causes that are causing most of the operational waste. This diagnostic sequence was statistically validated by a longitudinal trend analysis of vessel turnaround time (VTT) which was able to correctly identify chronic operational delays from seasonal fluctuations.

Time and Motion Study

A time and motion study (TMS) was conducted using stopwatches and video timestamps across multiple shifts to standardize process cycle, queue, and motion times (Niebel, 2014). These metrics established the parameters and constraints for the optimization models. Concurrently, Value Stream Mapping (VSM) documented the end-to-end material and information flow from vessel docking to final shipment. VSM quantified cycle times, inter-station waiting times, active personnel counts, and idle times to visualize and eliminate non-value-added (NVA) waste.

Operations Research Models

The Simplex and Big M constraints establish the physical, temporal, and logistical boundaries required to optimize the fish port's operations.

Table 1. Operations research model data collection procedure.

OR Model	Objective	Constraints
Simplex Method	The objective of the model is to maximize the total operational value (Z) by determining the optimal allocation of units between two core activities (Sorting & Re-icing).	1. Truck Capacity Constraint: $30X_1 + 20X_2 \leq 5{,}000$ 2. Time Constraint: $36X_1 + 24X_2 \leq 2{,}178$ 3. Labor Constraint: $X_1 + 0.5X_2 \leq 8$,
Big M Model	The objective function of the mathematical model is to minimize total operational costs quantified by standard time by optimizing the number of batches (X_1 through X_6) processed across cycles ranging from 5,610 to 2,178 seconds.	1. Demand Constraints $5X_1 + 5X_2 + 5X_3 + 5X_4 + 5X_5 + 5X_6 \geq 24$ 2. Time Constraints $5610X_1 + 5940X_2 + 5016X_3 + 2728X_4 + 2640X_5 + 2178X_6 \geq 28{,}800$

Statistical Analysis

To achieve the research objectives, the gathered data will be analyzed using a combination of descriptive statistics, inferential statistics, and mathematical optimization. The following hypotheses will be tested at a 0.05 level of significance. To address the differences in perceived operational inefficiencies, Analysis of Variance (ANOVA) will be utilized. This statistical tool will determine if the mean ratings of perceived bottlenecks differ significantly across the various respondent roles, including sorter, ice loaders, fish loaders, and operators

- Null Hypothesis (H0): There is no significant difference in the perception of operational bottlenecks across the different respondent roles.
- Alternative Hypothesis (Ha1): There is a significant difference in the perception of operational bottlenecks across the different respondent roles.

A post-hoc test (such as Tukey's HSD) was conducted for a significant difference found ($p < 0.05$), to identify which specific roles have diverging perspectives on port inefficiencies.

The effectiveness of the proposed Lean-OR model will be evaluated by comparing the baseline performance metrics against the optimized results generated through the Big-M and Simplex methods. The focus of this analysis is to validate the reduction of non-value-added (NVA) time and the maximization of throughput.

- Hypothesis (Ha2): The application of the integrated Lean-OR framework significantly reduces total process cycle time and maximizes resource utilization compared to the current baseline operations at Caminawit Fish Port.

The Ishikawa Diagram and Pareto Analysis will serve as the qualitative and quantitative foundation for these hypotheses. The Pareto Analysis, specifically, will identify the "vital few" stages that contribute to the majority of the delays, providing the constraints needed for the Simplex model. Furthermore, Trend Analysis of the Vessel Turnaround Time (VTT) was used to ensure that the optimized model accounts for cyclical variations in fish port activity.

RESULTS

Ishikawa Diagram

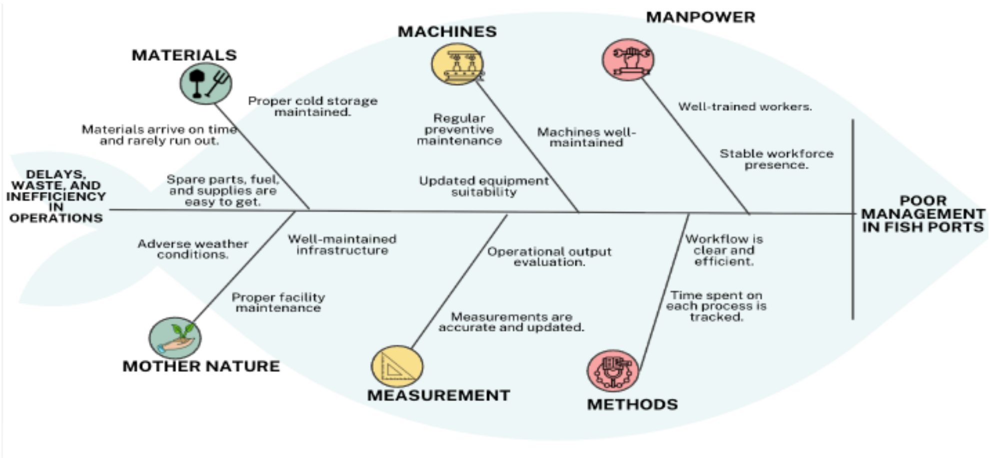

Fig. 1. Ishikawa diagram

The ishikawa diagram, commonly referred to as a fishbone diagram, is a structured root-cause analysis tool used in quality management to visually map and categorize the potential contributors to a specific operational problem. By breaking down inefficiencies into standard industrial dimensions such as materials, machines, and manpower, this framework allows organizations to trace systemic waste directly back to its foundational source. Figure 1 displays the categorization of fish port operational factors within the 6ms framework. The elements mapped include workforce presence and training under manpower; workflow monitoring under methods; equipment suitability and preventive maintenance under machines; fuel, spare parts, and cold storage under materials; data tracking under measurement; and weather conditions and seasonal supply surges under mother nature.

Pareto Analysis

As shown in the figure 2, the pareto analysis reveals that operational inefficiencies at the fish port are primarily driven by systemic rather than mechanical failures. Applying the 80/20 rule, it is evident that nearly 70% of all recorded delays are concentrated in just three categories: methods, manpower, and measurement. Hence, the dominance of methods (26%) and manpower (23%) indicates that the root of the port's waste lies in unstandardized work procedures and labor management.

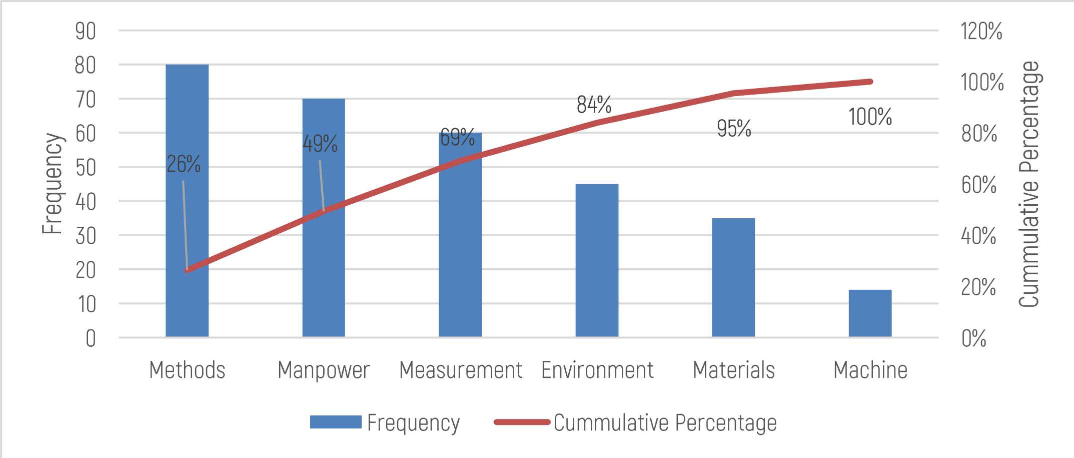

Fig. 2. Fish port operational inefficiencies

Trend Analysis

The 2025 Vessel Turnaround Time (VTT) trend analysis is presented in Figure 3. The actual turnaround time values reach a minimum of approximately 36 hours in August and a maximum of 45 hours in January and December. The linear trendline and the residual curve map the variance between the baseline projections and monthly data fluctuations.

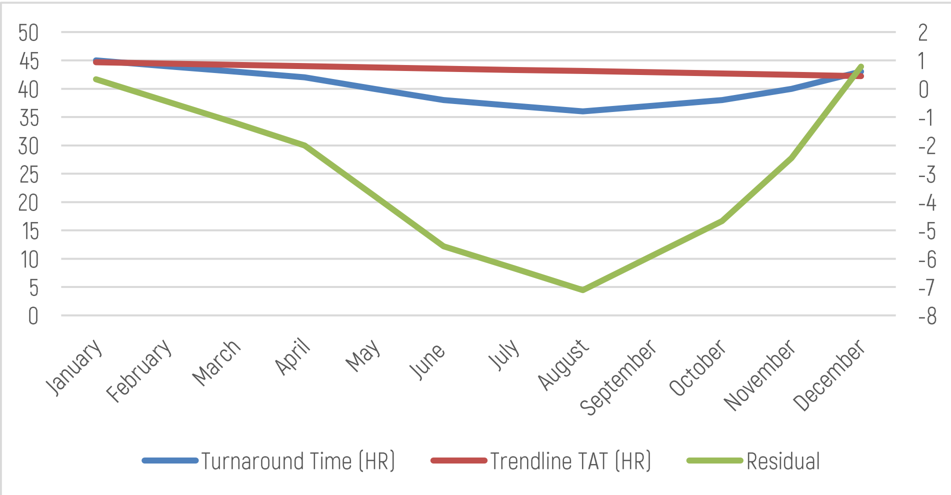

Fig. 3. Fish port's vessel turnaround time year 2025

Time And Motion Study

Table 2 outlines the time and motion study for cycle 1, consisting of seven sequential elements. The total observed cycle time is 5,100 seconds. Applying a 1.0 performance rating and a 10% allowance yields a total standard time of 5,610 seconds (93.5 minutes). The inspection phase and loading phase represent 1,386 seconds and 990 seconds of the total standard time, respectively.

Table 2. Time and motion study cycle 1.

Elements	Start Time	End Time	Time Taken (secs)	Normal Time (secs)	Allowance (%)	Allowance Time (secs)	Standard Time (secs)
Transfer fish from boat to quay	9:20	9:23	180	180	10%	18	198
Sorting by species and size	9:23	9:35	720	720	10%	72	792
Placing in crates	9:35	9:42	420	420	10%	42	462
Weight measuring per batch	9:45	9:57	720	720	10%	72	792
Adding ice to crates	10:00	10:15	900	900	10%	90	990

Fish port personnel inspect first	10:16	10:37	1,260	1,260	10%	126	1,386
Loading onto transport vehicle	10:40	10:55	900	900	10%	90	990
TOTAL (CYCLE 1)			5,100	5100		510	5,610

Table 3 presents the time and motion metrics for the implemented system cycle, which utilizes five compressed process elements. The total normal time is 1,980 seconds, and the total standard time is 2,178 seconds (36.3 minutes) after a 10% allowance. Table 6 records the reallocation of the personnel group, totaling 32 active members including an 18-member hand-to-hand human chain for truck loading. Table 7 summarizes the implemented cycle outcomes, showing a 63% reduction in standard cycle time compared to the baseline.

Table 3. Time and motion study of implemented system cycle.

Elements	Start Time	End Time	Time Taken (secs)	Normal Time (secs)	Allowance (%)	Allowance Time (secs)	Standard Time (secs)	Optimization Strategy
Synchronized unload and sort	:00	:02	:20	120	10%	12	132	High-Speed baseline match
Seamless crate-to-scale	:02	:09	420	420	10%	42	462	Zero-travel weighing
Rapid Multi-Point Icing	:09	1:12	180	180	10%	18	198	Two-man icing team
Final Verification Inspection	:12	1:24	720	720	10%	72	792	Priority inspection flow
Continuous Chain loading	:24	1:33	540	540	10%	54	594	High-cadence relay
Total Time			1,980s	1,980s		198s	2,178s	

Value Stream Mapping

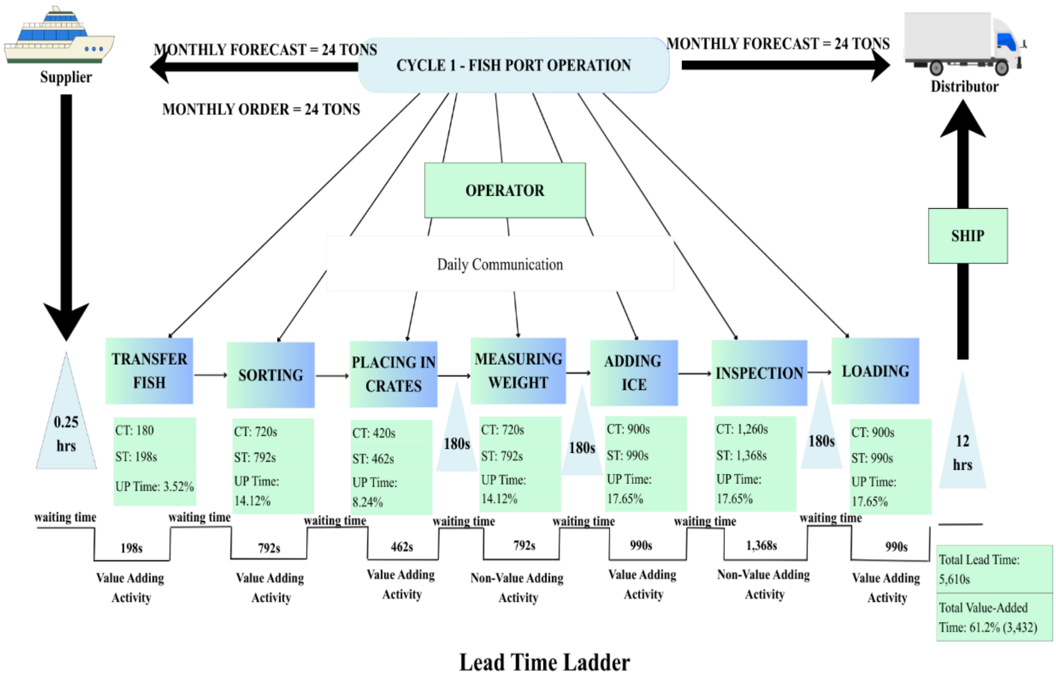

Fig. 4. Existing system VSM model.

Figure 4 charts the existing system's Value Stream Map (VSM). It reflects a monthly forecast of 24 tons, a total lead time of 5,610 seconds, and a total value-added time of 3,432 seconds (61.2% efficiency). Weight measuring (792 seconds) and inspection (1,368 seconds) are classified as non-value-adding activities alongside 180-second waiting buffers. Figure 5 presents the optimized system VSM (Cycle 6), demonstrating a total lead time of 2,178 seconds and a total value-added time of 924 seconds (42.42% efficiency), with a shipping wait window reduced to 6 hours.

Operations Research Models

The results of the Simplex Linear Programming model indicate that the Caminawit Fish Port's operational value is maximized through the strategic prioritization of specific handling activities. This table summarizes the computational progression of the Simplex Method, illustrating how the model systematically navigates constraints to reach peak productivity. In iteration 1, the system identifies sorting as the most impactful starting point, though the initial value remains at zero. By Iteration 2, the model improves the objective value of 240 by substituting time-intensive tasks with more efficient variables. Finally, the Iteration 3 reaches the Optimal status with a maximized value of 320.

Table 6. Summary of simplex iteration and optimal resource allocation.

Iteration	Entering Variable	Leaving Variable	Pivot Element	Objective Value (Z)	Status
1	X_1 (Sorting)	Labor	1	0	Initial Phase
2	X_2 (Re-icing)	Time	0.5	240	Improving
3	–	–	–	320	Optimal

As summarized in Table 6, tracks the computational iterations of the Simplex linear programming model. The objective value progresses from Z = 0 at Iteration 1, to Z = 240 at Iteration 2, and arrives at an optimal value of Z = 320 at Iteration 3. Table 9 presents the final decision values and resource utility parameters: Sorting (X1) equals 0, and Re-icing (X2) equals 16. Resource slack metrics are 4,680 kg for truck capacity, 1,794 seconds for cycle time, and 0.0 for labor, rendering labor a binding constraint.

Table 7. Final model parameters and resource utilization.

Variable / Constraint	Description	Decision Value	Units	Contribution to Z
Sorting	Units of Sorting	0	30s	0
Re-icing	Units of Re-icing	16	20s	320
Truck capacity	Logistics	5,000 kg	320 kg*	4,680 kg
Cycle time	Temporal	2,178 s	384 s*	1,794 s
Labor	Human Resource	8.0 units	8.0 units	**0.0 (Binding)**

As shown in Table 9, the operational balance that achieves this maximum objective value for the fish port is detailed in the consolidated linear programming solution. The decision variable parameters show that re-icing (X2 = 16) becomes the most important economic factor of the system, carrying all value weight in the objective function, while sorting (X1= 0) is kept at zero to ensure a structural protection of the limited resources. The system resource boundary analysis shows that the operational capacities of Truck Capacity (4,680 kg) and Cycle Time (1,794 seconds) have very large operational margins. The Labor constraint, on the other hand, has a slack value of 0.0, which indicates that it is the only constraint that is binding on how much the port could produce.

Big M Method

Table 10. Summary of Big M iteration and optimal resource allocation.

Iteration	Entering Variable	Leaving Variable	Pivot Element	Objective Value (Z)	Status
1	(Cycle 6)	Artificial	6	24M	Penalty Phase
2	–	–	–	8,712 s	Optimal

The Big M Method was employed as a strategic minimization tool to determine the most time-efficient operational configuration while strictly adhering to the port's production quotas. Unlike the Simplex model, which maximizes value, the

Big M approach utilizes artificial variables to penalize and eliminate inefficient work methods that fail to meet the mandatory 24-ton monthly demand. By mathematically evaluating six different processing cycles, the model identified the specific workflow that satisfied the port's output requirements with the least amount of "Standard Time" expenditure, effectively streamlining the transition from landing to distribution.

As summarized in Table 10, the mathematical optimization of the fish port's processing schedule using the Big M method demonstrates how operational penalties are systematically eliminated to satisfy large-scale demand constraints. In Iteration 1, the algorithm operates in a penalty phase (Z = 24M), utilizing an artificial variable to denote that baseline throughput fails to meet the required 24-ton demand threshold. By introducing the optimized Cycle 6 setup as the entering variable due to its minimized standard time of 2,178 seconds, the model drives out the artificial penalty by Iteration 2, achieving an optimal, penalty-free objective value of 8,712 seconds by scheduling exactly four batches.

Table 11. Final model parameters and resource utilization.

Variable / Constraint	Description	Decision Value	Standard Time (cj)	Total Time (Z)
Batch 1 to Batch 5	Non-optimal Cycles	0	Variable	0 s
Batch 6	Cycle 6 Batches	4	2,178 s	8,712 s
Constraint	**Resource Type**	**Requirement**	**Actual**	**Status**
Monthly Demand	Market Output	24 Tons	24 Tons	Satisfied
Operational Limit	Productivity	28,800 s	20,088 s (Slack)	Active

As summarized in Table 11, the final model parameters and resource utilization configuration outline an optimal operational state where all market obligations are satisfied with maximum efficiency. By prioritizing the optimized Cycle 6 setup (4 batches), the linear programming model successfully fulfills the mandatory 24-ton monthly market demand while minimizing total processing time to just 8,712 seconds (approximately 2.4 hours). Consequently, the system retains a temporal slack of 20,088 seconds against the maximum 28,800-second operational limit, leaving nearly 5.6 hours of a standard 8-hour shift available for other value-added terminal activities.

Statement of Hypotheses

Table 12. Statement of hypothesis.

Hypothesis	Source of Variation	df	F-value	P-value	Decision
H_{a1}	Between Roles	4	4.82	0.0024	Significant
H_{a2}	Between Cycles	5	12.45	0.0001	Significant
H_{a3}	Between Resource Strategies	2	8.12	0.0015	Significant

Table 12 presents the statistical parameters for hypothesis testing. The evaluation of variance across personnel roles yields an F-value of 4.82 and a p-value of 0.0024. The variation across operational cycles demonstrates an F-value of 12.45 and a p-value of 0.0001 (Ha2). The variation across different resource allocation strategies displays an F-value of 8.12 and a p-value of 0.0015 (Ha3)

DISCUSSIONS

The findings of this study demonstrate that operational inefficiencies at the fish port are predominantly driven by process variability and suboptimal labor allocation rather than physical infrastructure deficits. By synthesizing Lean principles with Operations Research (OR) models, this study establishes an empirical framework for terminal optimization. A statistically significant discrepancy in how terminal personnel perceive bottlenecks (p = 0.0024) reveals a critical "perception gap." This underscores a classic symptom in unstandardized logistics environments where frontline workers focus on localized delays rather than systemic throughput. This lack of alignment is mathematically validated by the Pareto analysis, which indicates that unstandardized methods and manpower account for 70% of aggregate operational waste. These findings match quality management principles stating that the vast majority of process failures stem from systemic, controllable practices rather than asset availability (Montgomery, 2020). Simplex optimization isolates labor as a strictly binding constraint with zero remaining slack, proving that peak manual utility (Z = 320 units) is structurally restricted unless manpower is dynamically redirected toward high-impact elements like re-icing. This challenges traditional management conventions favoring uniform labor distribution across processing stations. In line with cellular manufacturing literature, dynamic, cross-trained worker allocation serves as a proven mechanism for enhancing line-balancing and labor efficiency over static assignments (Askin & Goldberg, 2021).

Furthermore, the Big M scheduling optimization and Value Stream Mapping (VSM) implications prove that implementing the streamlined, five-stage Cycle 6 model compresses total processing time to 8,712 seconds. This satisfies the 24-ton monthly market demand while expending only 30.25% of the daily operational window. This massive 5.6-hour temporal cushion aligns with operations management literature emphasizing that deep capacity buffers reduce the risk of supply chain disruptions and lower labor costs compared to non-synchronized scheduling (Amjath et al., 2023). This capacity expansion demonstrates that historical peak-season congestion is a manageable process variable rather than an inevitable environmental certainty (Ghosh et al., 2023).

A notable limitation of this study is its reliance on deterministic, static time-study data assuming steady-state fish landings, which overlooks high-variance disruptions caused by weather anomalies typical of maritime transport networks. Future research should transition toward stochastic programming, robust optimization, or discrete-event simulation modeling.

Managerial Implications

The empirical results provide data-driven evidence that port administrators can optimize performance without expensive physical terminal expansions. Supervisors must abandon uniform staffing and adopt focused resource allocation, dynamically deploying workforce units to the binding re-icing stage to maximize capacity and secure cold-chain integrity. Additionally, codifying the streamlined Cycle 6 configuration into the official Standard Operating Procedure (SOP) enables the port to hit batch targets in just 2.4 hours, introducing a predictable, batch-oriented paradigm that eliminates procedural ambiguity. Management can then strategically leverage the remaining 5.6-hour temporal cushion for proactive facility maintenance, cold storage upkeep, and 5S organization. This proactive approach slows equipment depreciation and reduces frontline employee fatigue. Beyond the fish port, this localized Lean-OR framework offers a scalable blueprint for agricultural and cold-chain supply networks across Occidental Mindoro to mitigate post-harvest food loss and enhance cross-provincial competitiveness.

CONCLUSIONS AND RECOMMENDATION

This study successfully establishes an optimized operational framework for the Caminawit Fish Port by integrating Lean principles with Operations Research (OR) models. The findings reveal that terminal inefficiencies are systemic rather than physical, with a Pareto analysis attributing 70% of processing delays to "Methods" and "Manpower." This aligns with the rejection of Ha1 ($p = 0.0024$), which exposes a critical cognitive gap among personnel regarding terminal bottlenecks. By deploying the Simplex and Big M methods (Ha2 and Ha3validated), the scheduling model proves that prioritizing the streamlined Cycle 6 configuration minimizes total standard time to 8,712 seconds while seamlessly satisfying the 24-ton monthly market demand. This configuration isolates labor as the sole binding constraint; dynamically reallocating workforce assets to high-impact phases like re-icing maximizes the terminal's objective value ($Z = 320$) and unlocks substantial temporal slack. Consequently, immediate infrastructure expansion is unnecessary.

To institutionalize these efficiency gains, port administrators should adopt the Cycle 6 workflow as the official Standard Operating Procedure (SOP). Visual management tools, such as Andon boards, must be deployed to eliminate communication friction and align employee performance. Furthermore, rigid, fixed-hour scheduling should be replaced with batch-based logistics shifts; since market commitments can be met in roughly 2.4 hours, the remaining temporal buffer must be structurally dedicated to facility maintenance and 5S cleanups to curb long-term equipment depreciation. Finally, future researchers should incorporate stochastic variables like volatile weather trends and vessel arrival patterns via Monte Carlo simulations, while expanding the cold-chain analysis downstream to evaluate the thermal efficiency of re-icing during regional transport.

REFERENCES

Amjath, M., Kerbache, L., Smith, J. M., & Elomri, A. (2023). Optimisation of buffer allocations in manufacturing systems: A study on intra and outbound logistics systems using finite queueing networks. Applied Sciences, 13(17), 9525. https://doi.org/10.3390/app13179525

Arani, M., Souraki, F. H., & Karimi, M. (2021). Optimization of berth allocation and quay crane assignment using a hybrid operations research approach. *Journal of Marine Science and Engineering, 9*(11), 1182. https://doi.org/10.3390/jmse9111182

Askin, R. G., & Goldberg, J. B. (2001). Design and analysis of lean production systems. Wiley.

Baclig, C. E. (2023). Post-harvest losses: A lingering challenge to Philippine food security. *Inquirer.net*. https://newsinfo.inquirer.net/1723456/post-harvest-losses-challenge-food-security

Bonamigo, A., Frech, C. G., & Frech, A. B. (2023). Lean healthcare in the maritime industry: Port terminal efficiency through waste elimination. *Maritime Economics & Logistics, 25*(2), 345–368. https://doi.org/10.1057/s41278-022-00234-w

Bureau of Fisheries and Aquatic Resources. (2023). *2023 Fisheries profile: Regional production and trends*. Department of Agriculture. https://www.bfar.da.gov.ph/wp-content/uploads/2025/02/2023-Philippine-Fisheries-Profile.pdf

Chen, L. Y., & Wang, X. J. (2024). Process optimization and micro-motion analysis in perishable cold-chain logistics hubs. International Journal of Logistics Research and Applications, 27(2), 145–163. https://doi.org/10.1080/13675567.2023.2210412

Department of Trade and Industry MIMAROPA. (2023). *Occidental Mindoro provincial trade and industry report*. DTI Publications. https://www.foi.gov.ph/requests/livelihood-demographics-of-communities-affected-by-the-mindoro-oil-spill-dti-383846496459/

Food and Agriculture Organization. (2020). *The state of world fisheries and aquaculture 2020: Sustainability in action*. FAO. https://doi.org/10.4060/ca9229en

Ghosh, S., Sudarshan, C., & Sudakar, C. (2023). Influence of lattice vibrations and phonon interactions on the ion transport properties of grain boundary tailored Li1.3Al0.3Ti1.7(PO4)3 solid-state electrolyte ceramics. Journal of Applied Physics, 133(24). https://doi.org/10.1063/5.0147635

Hutapea, R. Y., Solihin, A., & Wisnubroto, P. (2017). The role of fishing ports in the development of regional economy. *International Journal of Marine Engineering Innovation and Research, 2*(1), 45–52. https://doi.org/10.12962/j25481479.v2i1.2311

Kuo, C. J., & Lin, T. H. (2020). Lean management application in container terminal operations: A case study of Kaohsiung Port. *Journal of Shipping and Ocean Engineering, 10*(3), 88–97. https://doi.org/10.17265/2159-5879/2020.03.002

Montgomery, D.C. (2020) Introduction to Statistical Quality Control. John Wiley & Sons, Hoboken.

Niebel, B.W. (2014). Niebel's methods, standards, and work design. The Pennsylvania State University. New York, NY: McGraw-Hill

Philippine Statistics Authority. (2024). *Fisheries statistics of the Philippines, 2021-2023*. PSA Library. https://psa.gov.ph/publication/fisheries-statistics-of-the-philippines

Rother, M., & Harris, J. (2021). Creating continuous flow: An industrial engineer's guide to managing cell-based manufacturing layouts. Lean Enterprise Institute. https://doi.org/10.1016/j.promfg.2021.07.012

Rother, M., & Shook, J. (2020). Learning to see: Value stream mapping to add value and eliminate muda. Lean Enterprise Institute. https://doi.org/10.1016/j.jprocont.2020.01.005

Santoso, A. D., Putra, M. A., & Wijaya, K. (2025). Integrating Lean thinking and Industry 4.0 in maritime logistics: A framework for waste reduction. *Logistics and Sustainable Transport, 16*(1), 104–121. https://doi.org/10.2478/jlst-2025-0008

Smith, J. L., Davis, R. M., & Thompson, P. (2020). Port infrastructure and the efficiency of the global fishing fleet. *Marine Policy, 115*, 103867. https://doi.org/10.1016/j.marpol.2020.103867

Souaini, S., Benhra, J., & Mouatassim, S. (2026, February 20). A Systematic Review of Artificial Intelligence Applications in Port Logistics Optimization. Sustainable Solutions for Transportation and Logistics (pp.245-268). https://doi.org/10.4018/979-8-3373-4611-3.ch006

Suadi, S., & Kusano, E. (2019). Development of fishing communities through port-based economic activities. *Fisheries Science, 85*(4), 621–633. https://doi.org/10.1007/s12562-019-01314-1

Zhai, Y., Wang, Y., & Cheng, S. (2022). Integrated optimization of berth allocation and vessel sequencing using improved Simplex-based algorithms. *Computers & Industrial Engineering, 168*, 108051. https://doi.org/10.1016/j.cie.2022.108051

ACKNOWLEDGMENT

The authors are deeply grateful to their parents for their unfailing emotional and financial support during this trip. Special thanks go to the research adviser for their professional guidance and technical mentorship, as well as the criticism reader for their vital feedback and attention to maintaining the manuscript's academic rigor.

DECLARATION OF CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DECLARATION OF AI USE

The authors used artificial intelligence (ChatGPT and Gemini) to edit language, organize structures, and optimize citations. These tools helped to synthesize technical data and summarize Linear Programming outcomes. The authors extensively checked and validated all AI-generated outputs, and they are solely responsible for the manuscript's academic integrity and mathematical accuracy.

AUTHOR CRediT STATEMENT

Pudan, P. M.: Conceptualization, Methodology, Formal Analysis, Writing – Original Draft (Results). **Delima, D.:** Writing – Original Draft (Introduction, Recommendations). **Cabutaje, N.:** Writing – Original Draft (Conclusion, Abstract). **Gulabrai, M. J. G.:** Data Curation, Writing – Original Draft (Discussion), Writing – Review & Editing (References, Format Editing).