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Annex IV Marine Pollution (MARPOL) Application for Pollution Prevention on Ketapang-Gilimanuk Route Crossing Vessels with Analytical Hierarchy Process (AHP) Method

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***Abstract*— The Application of the Marine Pollution (MARPOL) Annex IV regulation concerning sewage discharge from ferry ships operating on the Ketapang-Gilimanuk route plays a crucial role in pollution prevention. However, this essential role has been compromised due to suspicions that sewage waste from the Ketapang-Gilimanuk ferry ships is being directly discharged into the sea. Additionally, it is believed that the lack of sewage storage facilities at the port and inadequate supervision by local port authorities contribute to this issue. This research aims to investigate the implementation of MARPOL Annex IV in pollution prevention on ferry ships along the Ketapang – Gilimanuk route using the Analytical Hierarchy Process (AHP) method. This method is employed to establish a comprehensive evaluation framework by considering criteria such as safety management systems, safety and environmental protection policies, Company responsibilities and authorities, cultural and behavioral aspects, organizational factors, and technical considerations. Data will be collected through surveys and interviews with ship operators and members. Economical is more priority than operational techniques because it is related to capital expenditure and operational costs of each alternative to prevent marine pollution. Operational techniques are more priority than safety and environment because they are related to the technical and operational of each alternative to preventing marine pollution. Regulations are more priority than safety and environment because regulations affect each alternative, both Indonesian regulations and also SOPs at ports.**

Keywords: MARPOL Annex IV, pollution, sewage, ferry ships, Analytical Hierarchy Process (AHP).

I. INTRODUCTION

Shipping is one of the modes of transportation that is the backbone of global trade where 4/5 of the volume of goods traded is carried by sea [1]. Although considered an efficient mode of transportation, shipping cannot be separated from marine pollution. The definition of marine pollution is the entry of substances or energy directly or indirectly into the marine environment (including estuaries) by humans, resulting in losses to biological resources, hazards to human health, disruption to marine activities including fishing, degradation of seawater quality and reduction of facilities [2]. The International Maritime Organization (IMO) as a world body in international shipping regulation has responsibilities in the field of safety, security, and protection of the marine environment. Related to the protection of the marine environment, IMO has an instrument, namely the International Convention for the Prevention of Pollution from Ships (MARPOL) [3].

The MARPOL Convention originated from the prevention of marine pollution caused by the oil spill from the Torrey Canyon Disaster in 1967. Over time, this convention also regulates the prevention of pollution due to chemicals, packaged goods, sewage, garbage, and air pollution. Each is written in the Annex to each convention [4].

One of the preventions of pollution in MARPOL is related to sewage or sewage water. Discharge of wastewater into the sea can pose a health hazard to humans. Sewage can also cause oxygen depletion and can be obvious visual pollution in coastal areas, which can be a problem for countries with tourism industries [5]. Furthermore, wastewater, because it is toxic, can have adverse effects on coral reefs by causing changes in coral metabolism, decreased growth and reproduction rates, and decreased coral survival [6].

Some of the problems that arise from the implementation of pollution prevention from common sewage include the inability to sail offshore where disposal is permitted, the lack of wastewater reception facilities at local ports, the lack of adequate application of laws, and the lack of responsibility for ecological awareness. In addition, small holding tanks are very limited and often fill up quickly and need to be emptied immediately [7].

Research by M Dicky Armanda [8] explains how important environmental law is to control human actions that damage the environment. Environmental protection

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and management outside national borders are governed by international environmental law such as MARPOL 73/78 and other conventions. Today, marine pollution, especially marine pollution, is considered one of the main problems threatening the Earth. To preserve natural heritage, the protection of the ocean from pollution is essential. The author mentions several provisions in International Environmental Law relating to efforts to maintain natural heritage in the sea, such as MARPOL 73/78 Annex 4, CLC 1969 and its Protocol 1992, London Convention 1972, OPRC 1990, and UNCLOS 1982. [9].

Yulianto and Ari Varanita's research [10] states that one of the main issues discussed in this journal is the pollution of Indonesian waters by ships operating in the region. The amount of garbage polluting the sea also increases along with the number of ships operating each year. This can affect ecosystems in Indonesian waters and seawater quality.

Arnaldy Achmadita's research [11] explained that ships at Biringkasi Port did not meet several requirements of MARPOL Annex I, such as tanks for oil or sludge residues, standard discharge connections, oil filter equipment, oil discharge control, and oil logbooks. In addition, the ship's sailing length is too short, piping connections are not up to standard, lack of oil filter equipment, and lack of oil residue handling.

Marine pollution has become a serious problem, whether it is rubbish from ships or from land [12]. Garbage collection and cleaning technologies began to emerge and continue to develop [13]. A small boat with a garbage collection system was proposed [14]. Furthermore, research on the effect of the shape of the holes in the conveyor wing on the effectiveness in garbage collection was conducted [15]. The innovation research on the variation of conveyor location in shisp was also conducted [16].

Problems in the implementation of pollution prevention from sewage also occur in Indonesia, especially on Ro-ro ship voyages. One of the Ro-ro ships routes that will be raised as a case study in this thesis is the shipping route between Ketapang-Gilimanuk. This route connects Ketapang Crossing Port located in Banyuwangi Regency, East Java to Gilimanuk Crossing Port in the western part of Bali Island. Both ports are managed by PT. River, Lake, and Crossing Transport (ASDP) Indonesia Ferry (Persero). The crossing from Ketapang Port to the Port can be reached in about 35 minutes until the berth (± 4 nautical miles) [17].

In some cases, sewage waste from ships on the Ketapang – Gilimanuk route is directly discharged into the sea without special treatment. This is due to the unavailability of sewage waste collection facilities at the port. Therefore, this study aims to provide solutions regarding the application of MARPOL Annex IV in preventing pollution on crossing vessels on the Ketapang-Gilimanuk passage. The results of this study are expected to provide better solutions on the factors affecting the implementation of MARPOL Annex IV and contribute to the improvement of existing practices to preserve the maritime environment on the Ketapang – Gilimanuk track.

II. RESEARCH METHODS

This study uses the Analytical Hierarchy Process (AHP) method. Decision-making has become an increasingly difficult challenge amid the complexity of the modern world. Decisions made in business, science, or everyday life can greatly affect results. Analytical Hierarchy Process (AHP) is a tool created to make the decision-making process more measurable and structured.

The Analytical Hierarchy Process (AHP) has many advantages, including a measurable decision-making structure, the ability to analyze sensitivities, the ability to adapt to different types of problems, and the ability to give weight to criteria. Overall, AHP helps in overcoming complexity and uncertainty in decision making. Therefore, this approach becomes a powerful and customizable tool to deal with decision-making challenges in various aspects of life. (Lyu, 2020).

2.1. Data Collection

In this case, the subject of research is the implementation of MARPOL Annex IV in the prevention of pollution on crossing vessels operating on the Ketapang – Gilimanuk passage. The focus of the research will be on how the rules and regulations regulated by MARPOL Annex IV are applied and applied to crossing vessels operating on the passage. The research will assess how the vessels comply with the regulations and standards set by MARPOL Annex IV, as well as how appropriate technology is used to prevent pollution.

The research will consider additional elements such as the participation and engagement of relevant stakeholders, including vessel operators, maritime authorities, and relevant environmental organizations. The purpose of this study is to find out how involved stakeholders are in pollution prevention and whether there are challenges or obstacles faced in the implementation of MARPOL Annex IV.

In this study, there are various data collection techniques used to obtain complete and relevant data on the implementation of MARPOL Annex IV and efforts to reduce pollution on crossing vessels on the Ketapang-Gilimanuk passage.

The study sample was a crossing ship that received a questionnaire. These questions relate to pollution prevention efforts, the technology used, the implementation of MARPOL Annex IV, and understanding of applicable regulations. In addition, the survey involves ship operators, crews, and other relevant parties to obtain information from various points of view.

Direct interviews were conducted with respondents such as ship operators and ship crew. To obtain more in-depth and qualitative data, this interview is very important. By conducting interviews, researchers can

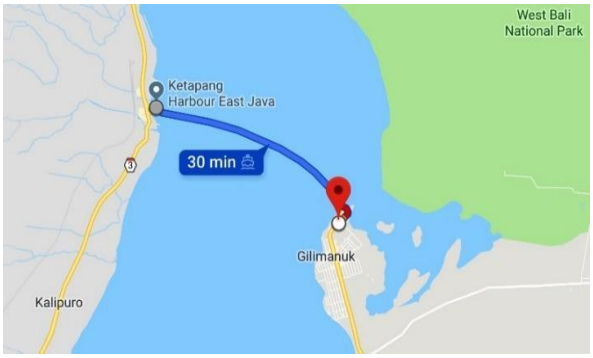

Figure 1. Routes

gain an understanding of the challenges faced, the challenges faced to implement, and stakeholder perspectives on pollution prevention efforts. At the time of the interview, researchers already had 3 (three) criteria along with alternative facilities that support efforts to prevent pollution of Ketapang - Gilimanuk crossing ships. Here is a breakdown of some of the alternatives that will be asked of respondents.

a. Technical Operational
- Installation facilities
- Operational/maintenance facilities
- Duration of suction to ship operations

b.Economy
- Cost of manufacture
- Operating and Maintenance Costs

c. Safety and Environment
- Safety against humans
- Safety against the ship
- Potential spills of marine pollution

d. Regulation
- Regulatory compliance
- Compatibility with Port SOP

In addition, to obtain data on the physical condition of ships, the application of pollution prevention technologies, and compliance with MARPOL Annex IV regulations, direct observation in the field is used. These observations provide accurate and valid data on actual conditions on crossing vessels.

2.2. Instructions and Alternative Explanations

The questionnaire from AHP consists of a comparison between two criteria to determine which is more priority or important between criteria. Ladies and gentlemen ask us to assess the criteria by ticking (✓) the box provided on the questionnaire. The number indicates the importance of the criteria, sub-criteria or alternatives. Here is the rating scale used to compare the elements in question.

Filling in the Table 1 above means that Element 1 is more important than Element 2. Filling in the priority scale on the right would mean prioritizing or preferring Element 2 over Element 1.

Information:

1. The criteria will be compared between the criteria in the leftmost column with the criteria in the rightmost column
2. There are two scales on the left and on the right, where the left is a scale that means prioritizing criteria in the left column and on the right which means prioritizing criteria in the right column
3. Put a check mark (✓) on the scale column according to the importance value between two elements

TABLE 1. RATING SCALES

Rating Scale	
Nilai	Defines
1	**Equally important** or equivalent comparison between elements
3	One element **is slightly more important** than the other
5	One element **is more important** than the other
7	One element **is more important** than the other
9	The element of one is **most important** or **absolutely most important** of the others

III. RESULTS AND DISCUSSION

The Ketapang-Gilimanuk shipping route is one of the most congested shipping routes in Indonesia. This route generally connects land transportation modes between Java Island and Bali Island. Operationally, ships operate (fill in the average size of the ship) and the voyage takes approximately 45 minutes. On this shipping route, the distance traveled per trip is 4 miles shown in Figure 1. When it comes to regulations related to environmental pollution, especially to sewage, ships sailing on this route must have a pipeline connection to land, have sewage crushing and disinfectant system equipment, or have a holding tank. In addition, as ships sail at distances of less

than 12 miles, sewage holding tanks are mandatory on ships and only discharge sewage at available sewage holding facilities.

In the SOP of the ASDP Port, there is no adequate flow of sewage from the ship so this research alternatives are:

intends to provide an alternative onshore sewage storage facility that can be applied so that the sewage on the ship is not directly discharged into the sea freely. There are 3 alternatives proposed in this study, which will then be analyzed using the AHP selection method. These

1. Discharge using flexible hose to tank on land.

Figure 2. Alternatif I Ship to Tank

2. Discharge using a tank car that enters the ship.

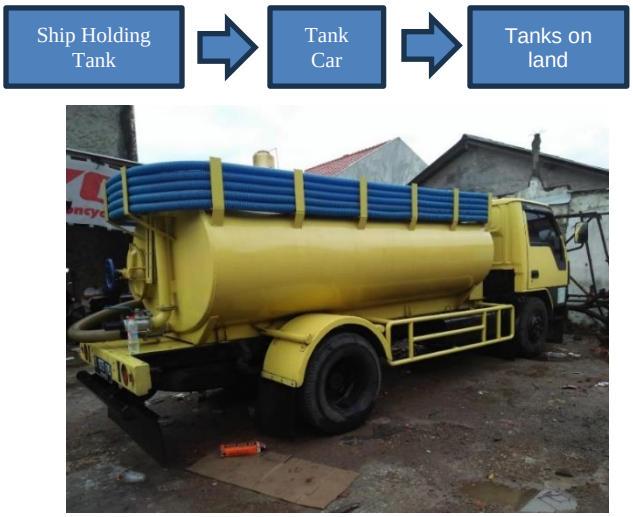

Figure 3. Alternatif II Ship to Truck

3. Disposal using a barge attached to the ship can be done when the ship is off schedule .

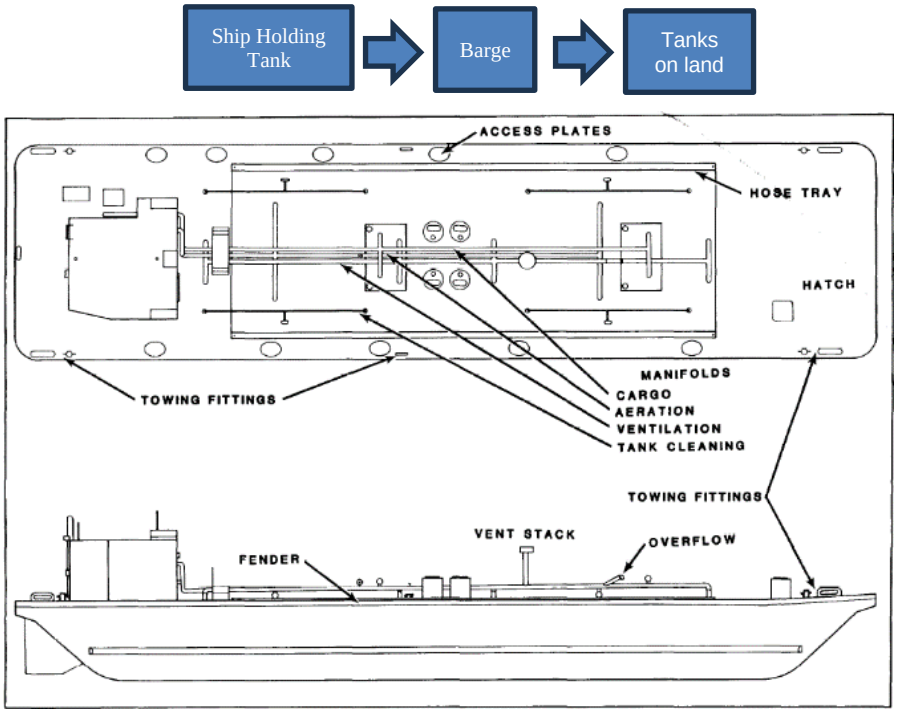

Figure 4. Alternatif II Ship to Barge

From the existing alternatives, the selection was made on 4 criteria with each sub-criteria. The criteria compared are technical-operational, economic, safety and environment, and regulation. Each sub-criterion can be shown in the following Figure 5.

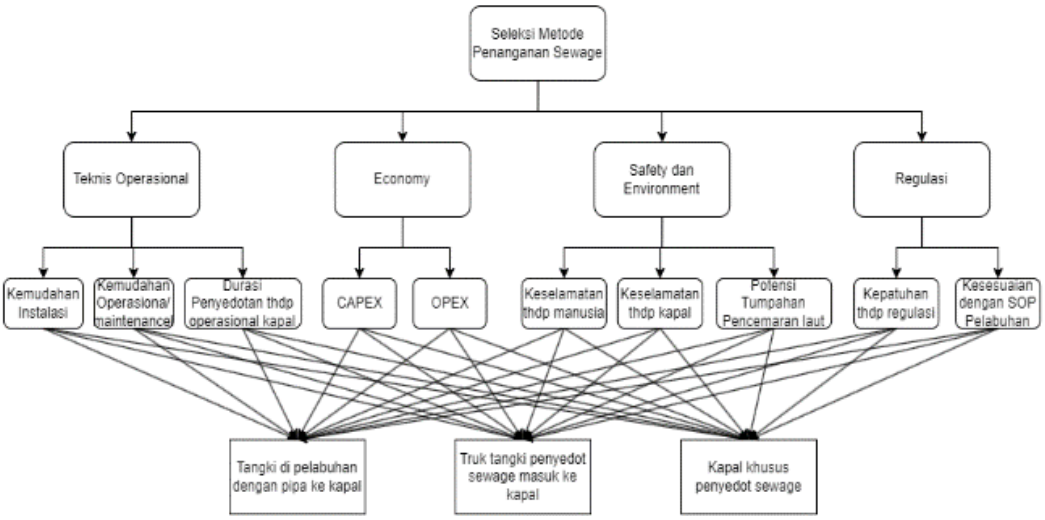

Figure 5. Alternative Selection

3.1. Inter-Criteria Comparison

The criteria used in the sele ction for this study consisted of:

- *Technical Operations*

This criterion assesses the influence of technical and operational options on each alternative to preventing marine pollution.

- *Economy*

This criterion assesses the effect of choices related to capital expenditure and operational costs of each alternative to marine pollution prevention.

- *Safety and Environment*

This criterion assesses the effect of safety on humans (crew) and also on the environment due to the sewage spill.

- *Regulation*

This criterion assesses the effect of regulations on each alternative, both Indonesian regulations and also SOPs at ports.

TABLE 2. RATING SCALES INTER-CRITERIA TECHNICAL OPERATIONAL AND ECONOMY

Criterion	Priority Scale									Criterion
Technical – Operational	9	7	5	3	1	3	5	7	9	**Economy**
			✓						✓	

Following Table 2 can be shown Economical is more priority than operational techniques because it is related to capital expenditure and operational costs of each alternative to prevent marine pollution.

TABLE 3. RATING SCALES INTER-CRITERIA TECHNICAL OPERATIONAL AND SAFETY AND ENVIRONMENT

Criterion	Priority Scale									Criterion
Technical - Operational	9	7	5	3	1	3	5	7	9	**Safety and Environment**
		✓					✓			

Following Table 3 can be shown Operational techniques are more priority than safety and environment because they are related to the technical and operational of each alternative to preventing marine pollution.

TABLE 4. RATING SCALES INTER-CRITERIA TECHNICAL OPERATIONAL AND REGULATION

Criterion	Priority Scale									Criterion
Technical – Operational	9	7	5	3	1	3	5	7	9	**Regulation**
	✓						✓			

Following Table 4 can be shown Operational techniques are more priority than regulations because they are related to the technical and operational of each alternative to preventing marine pollution.

TABLE 5. RATING SCALES INTER-CRITERIA ECONOMY AND SAFETY AND ENVIRONMENT

Criterion	Priority Scale									Criterion
Economy	9	7	5	3	1	3	5	7	9	**Safety and Environment**
	✓						✓			

Following Table 5 can be shown Economical is more priority than safety and environment because of the technical and operational aspects of each alternative to preventing marine pollution.

TABLE 6. RATING SCALES INTER-CRITERIA ECONOMY AND REGULATION

Criterion	Priority Scale									Criterion
Economy	9	7	5	3	1	3	5	7	9	**Regulation**
	✓						✓			

Following Table 6 can be shown Economical is more priority than regulation because of the technical and operational aspects of each alternative to preventing marine pollution.

TABLE 7. RATING SCALES INTER-CRITERIA SAFETY AND ENVIRONMENT AND REGULATION

Criterion	Priority Scale									Criterion
Safety and Environment	9	7	5	3	1	3	5	7	9	**Regulation**
	✓						✓			

Following Table 7 can be shown Economical is more priority than safety and environment because of the technical and operational aspects of each alternative to preventing marine pollution.

3.2. Comparison between operational technical sub-criteria

The sub-criteria used in the selection for this study consist of:

• Ease of Installation

This sub-criterion assesses the effect of the choice of ease of installation/manufacture of each alternative.

• Ease of Operation/Maintenance

This criterion assesses the effect of choice regarding the ease of operation/maintenance of each alternative.

• Duration of suction to ship operations

This criterion assesses the effect of suction duration on ship operations.

TABLE 8. RATING SCALES OPERATIONAL TECHNICAL SUB-CRITERIA ON INSTALLATION AND MAINTENANCE

Criterion	Priority Scale									Criterion
Ease of Installation	9	7	5	3	1	3	5	7	9	**Ease of Operation/Maintenance**
	✓							✓		

Following Table 8 can be shown Ease of Installation is more priority than Ease of Operation / Maintenance because of the ease of installation / manufacture of each alternative.

TABLE 9. RATING SCALES OPERATIONAL TECHNICAL SUB-CRITERIA ON INSTALLATION AND DURATION SUCTION

Criterion	Priority Scale									Criterion
Ease of Installation	9	7	5	3	1	3	5	7	9	**Duration of suction to ship operations**
	✓						✓			

Following Table 9 can be shown Ease of installation takes priority over the ease of suction duration of ship operations because of the ease of installation/manufacture of each alternative.

TABLE 10. RATING SCALES OPERATIONAL TECHNICAL SUB-CRITERIA ON MAINTENANCE AND DURATION SUCTION

Criterion	Priority Scale									Criterion
Ease of Operation/Maintenance	9	7	5	3	1	3	5	7	9	**Duration of suction to ship operations**
		✓					✓			

Following Table 10 can be shown Ease of Operation/Maintenance is more priority than the duration of suction of ship operations because of the ease of operation/maintenance of each alternative.

3.3. Comparison between economic sub-criteria

The sub-criteria used in the selection for this study consist of:

• Capital Expenditure

This sub-criterion assesses the effect of the choice of ease of installation/manufacture of each alternative.

• Operational Expenditure

This criterion assesses the effect of choice regarding the ease of operation/maintenance of each alternative.

TABLE 11. RATING SCALES ECONOMIC SUB-CRITERIA ON CAPEX AND OPEX

Criterion	Priority Scale									Criterion
CAPEX	9	7	5	3	1	3	5	7	9	**OPEX**
	✓							✓		

Following Table 11 can be shown CAPEX is more priority than OPEX because of the ease of installation/manufacture of each alternative.

3.4. Comparison Between Safety Sub-Criteria

The sub-criteria used in the selection for this study consist of:

• Safety against man

This sub-criterion assesses the effect of safety choices on humans on each alternative.

• Safety of the ship

This criterion assesses the effect of safety-related choices of ships on each alternative.

• Potential Marine Pollution Spills

This criterion assesses the effect of choice on potential marine spillage from each alternative

TABLE 12. RATING SCALE BETWEEN SAFETY SUB-CRITERIA ON HUMAN AND SHIP

Criterion	Priority Scale									Criterion
Safety against man	9	7	5	3	1	3	5	7	9	**Safety of the ship**
	✓							✓		

Following Table 12 can be shown Safety of people is more priority than safety of ships because safety of humans in each alternative is more priority.

TABLE 13. RATING SCALE BETWEEN SAFETY SUB-CRITERIA ON HUMAN AND POLLUTION

Criterion	Priority Scale									Criterion
Safety against man	9	7	5	3	1	3	5	7	9	**Potential marine pollution spills**
	✓						✓			

Following Table 13 can be shown Human safety is more priority than potential marine pollution spills because human safety in each alternative is more priority.

TABLE 14. RATING SCALE BETWEEN SAFETY SUB-CRITERIA ON SHIP AND POLLUTION

Criterion	Priority Scale									Criterion
Safety of the ship	9	7	5	3	1	3	5	7	9	**Potential marine pollution spills**
		✓					✓			

Following Table 14 can be shown Safety of ships is more priority than potential marine pollution spills because the safety of ships in each alternative is more priority.

3.5. Comparison between regulatory sub-criteria

The sub-criteria used in the selection for this study consist of:

- Regulation

This sub-criterion assesses the effect of compliance options on regulation on each alternative

- Compliance with Port SOPs

This criterion assesses the effect of compliance options on port SOPs on each alternative

TABLE 15. RATING SCALE BETWEEN REGULATORY SUB-CRITERIA ON REGULATION AND SOP

Criterion	Priority Scale									Criterion
Regulation	9	7	5	3	1	3	5	7	9	**Port SOP Compliance**
	✓							✓		

Following Table 15 can be shown Regulation is more priority than Port SOP Conformity because it complies with regulations on each alternative.

3.6. Comparison Between Alternatives on Ease of Installation

The higher the value, the more preferable and easier in terms of ease of installation

TABLE 16. RATING SCALE BETWEEN ALTERNATIVES ON EASE OF INSTALLATION IN PORT TANK AND TANKER TRUCK

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Tanker Truck**
	✓						✓			

Following Table 16 can be shown Port tanks are more priority than Tank Trucks because Port tanks are easier to install.

TABLE 17. RATING SCALE BETWEEN ALTERNATIVES ON EASE OF INSTALLATION IN PORT TANK AND BARGE

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Barge**
	✓							✓		

Following Table 17 can be shown Port tanks are more priority than Barge because Port tanks are easier to install.

TABLE 18. RATING SCALE BETWEEN ALTERNATIVES ON EASE OF INSTALLATION IN TANKER TRUCK AND BARGE

Criterion	Priority Scale									Criterion
Tanker Truck	9	7	5	3	1	3	5	7	9	**Barge**
			✓					✓		

Following Table 18 can be shown Tanker Trucks are more priority than Barge because Port tanks are easier to install.

3.7. Comparison Between Alternatives in Ease of Operation/Maintenance

The higher the value, the more preferable and easier it is in terms of operation/maintenance

TABLE 19. RATING SCALE BETWEEN ALTERNATIVES ON EASE OF OPERATION/MAINTENANCE IN PORT TANK AND TANKER TRUCK

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Tanker Truck**
	✓						✓			

Following Table 19 can be shown Port Tanks are more priority than Tank Trucks because of Ease of Operation/Maintenance.

TABLE 20. RATING SCALE BETWEEN ALTERNATIVES ON EASE OF OPERATION/MAINTENANCE IN PORT TANK AND BARGE

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Barge**
	✓							✓		

Following Table 20 can be shown Port Tank is more priority than Barge because of Ease of Operation / Maintenance.

TABLE 21. RATING SCALE BETWEEN ALTERNATIVES ON EASE OF OPERATION/MAINTENANCE IN TANKER TRUCK AND BARGE

Criterion	Priority Scale									Criterion
Tanker Truck	9	7	5	3	1	3	5	7	9	**Barge**
			✓					✓		

Following Table 21 can be shown Tanker Trucks are more priority than Barge because of Ease of Operation/Maintenance.

3.8. Comparison Between Alternatives on the Suction Duration of Ship Operations

The higher the value, the more preferable and faster in suction.

TABLE 22. RATING SCALE BETWEEN ALTERNATIVES ON THE SUCTION DURATION OF SHIP OPERATIONS IN PORT TANK AND TANKER TRUCK

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Tanker Truck**
	✓						✓			

Following Table 22 can be shown Port Tanks are more priority than Tank Trucks because the Suction Duration of Ship Operations is more Alternative.

TABLE 23. RATING SCALE BETWEEN ALTERNATIVES ON THE SUCTION DURATION OF SHIP OPERATIONSIN PORT TANK AND BARGE

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Barge**
	✓							✓		

Following Table 23 can be shown Port Tanks are more priority than Barge because the Duration of Suction of Ship Operations is more Alternative.

TABLE 24. RATING SCALE BETWEEN ALTERNATIVES ON THE SUCTION DURATION OF SHIP OPERATIONS IN TANKER TRUCK AND BARGE

Criterion	Priority Scale									Criterion
Tanker Truck	9	7	5	3	1	3	5	7	9	**Barge**
			✓					✓		

Following Table 24 can be shown Tanker Trucks are more priority than Barges because the Duration of Suction of Ship Operations is more Alternative.

3.9. Comparison Between Alternatives on Manufacturing Cost (CAPEX)

The higher the value, the more preferable and cheaper it is related to CAPEX

TABLE 25. RATING SCALE BETWEEN ALTERNATIVES ON MANUFACTURING COST (CAPEX) IN PORT TANK AND TANKER TRUCK

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Tanker Truck**
	✓							✓		

Following Table 25 can be shown Port Tanks are more priority than Tank Trucks because Manufacturing Cost (CAPEX) is more Alternative.

TABLE 26. RATING SCALE BETWEEN ALTERNATIVES ON MANUFACTURING COST (CAPEX) IN PORT TANK AND BARGE

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Barge**
	✓						✓			

Following Table 26 can be shown Port Tank is more priority than Barge because Manufacturing Cost (CAPEX) is more Alternative.

TABLE 27. RATING SCALE BETWEEN ALTERNATIVES ON MANUFACTURING COST (CAPEX) IN TANKER TRUCK AND BARGE

Criterion	Priority Scale									Criterion
Tanker Truck	9	7	5	3	1	3	5	7	9	**Barge**
		✓					✓			

Following Table 27 can be shown Tanker Trucks are more priority than Barge because Manufacturing Cost (CAPEX) is more Alternative.

3.10. Comparison Between Alternatives to Operating and Maintenance Costs (OPEX)

The higher the value, the preferable and cheaper it is associated with OPEX.

TABLE 28. RATING SCALE BETWEEN ALTERNATIVES TO OPERATING AND MAINTENANCE COSTS (OPEX) IN PORT TANK AND TANKER TRUCK

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Tanker Truck**
	✓						✓			

Following Table 28 can be shown Port Tanks are more priority than Tank Trucks because Operating and Maintenance Costs (OPEX) are more Alternative.

TABLE 29. RATING SCALE BETWEEN ALTERNATIVES TO OPERATING AND MAINTENANCE COSTS (OPEX) IN PORT TANK AND BARGE

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Barge**
	✓							✓		

Following Table 29 can be shown Port Tanks are more priority than Barge because Operating and Maintenance Costs (OPEX) are more Alternative.

TABLE 30. RATING SCALE ALTERNATIVES TO OPERATING AND MAINTENANCE COSTS (OPEX) IN TANKER TRUCK AND BARGE

Criterion	Priority Scale									Criterion
Tanker Truck	9	7	5	3	1	3	5	7	9	**Barge**
			✓					✓		

Following Table 30 can be shown Tanker Trucks are more priority than Barge because Operating and Maintenance Costs (OPEX) are more Alternative.

3.11. Comparison of Alternatives to Human Safety

The higher the value, the more preferable and safer it is for humans.

TABLE 31. RATING SCALE BETWEEN ALTERNATIVES TO HUMAN SAFETY IN PORT TANK AND TANKER TRUCK

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Tanker Truck**
	✓						✓			

Following Table 31 can be shown Port Tanks are more priority than Tank Trucks because Human Safety is safer.

TABLE 32. RATING SCALE BETWEEN ALTERNATIVES TO HUMAN SAFETY IN PORT TANK AND BARGE

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Barge**
	✓						✓			

Following Table 32 can be shown Port tanks are more priority than Barge because human safety is safer.

TABLE 33. RATING SCALE BETWEEN ALTERNATIVES TO HUMAN SAFETY IN TANKER TRUCK AND BARGE

Criterion	Priority Scale									Criterion
Tanker Truck	9	7	5	3	1	3	5	7	9	**Barge**
		✓					✓			

Following Table 33 can be shown Tanker trucks are more priority than Barge because human safety is safer.

3.12. Comparison of Alternatives to Ship Safety

The higher the value, the more preferable and safer it is for the ship.

TABLE 34. RATING SCALE BETWEEN ALTERNATIVES TO SHIP SAFETY IN PORT TANK AND TANKER TRUCK

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Tanker Truck**
		✓					✓			

Following Table 34 can be shown Port Tanks are more priority than Tank Trucks because Safety of ships is safer.

TABLE 35. RATING SCALE BETWEEN ALTERNATIVES TO SHIP SAFETY IN PORT TANK AND BARGE

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Barge**
		✓							✓	

Following Table 35 can be shown Barge is more priority than Port Tank because Safety of ships is safer.

TABLE 36. RATING SCALE BETWEEN ALTERNATIVES TO SHIP SAFETY IN TANKER TRUCK AND BARGE

Criterion	Priority Scale									Criterion
Tanker Truck	9	7	5	3	1	3	5	7	9	**Barge**
			✓						✓	

Following Table 36 can be shown Barge is more priority than Tanker Trucks because Safety of ships is safer.

3.13. Comparison Between Alternatives to Potential Marine Pollution Spills

The higher the value, the preferable and safer there is no spillage of marine pollution.

TABLE 37. RATING SCALE BETWEEN ALTERNATIVES TO POTENTIAL MARINE POLLUTION SPILLSIN PORT TANK AND TANKER TRUCK

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Tanker Truck**
		✓							✓	

Following Table 37 can be shown Tanker Trucks are more priority than Port Tanks because the Potential for Marine Pollution Spills is safer.

TABLE 38. RATING SCALE BETWEEN ALTERNATIVES TO POTENTIAL MARINE POLLUTION SPILLS IN PORT TANK AND BARGE

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Barge**
		✓					✓			

Following Table 38 can be shown Port tanks are more priority than barges because the potential for marine pollution spills is safer.

TABLE 39. RATING SCALE BETWEEN ALTERNATIVES TO POTENTIAL MARINE POLLUTION SPILLSIN TANKER TRUCK AND BARGE

Criterion	Priority Scale									Criterion
Tanker Truck	9	7	5	3	1	3	5	7	9	**Barge**
	✓						✓			

Following Table 39 can be shown Tanker Trucks are more priority than Barge because the Potential for Marine Pollution Spills is safer.

3.14. Comparison Between Alternatives to Regulatory Compliance

The higher the value, the more you prefer and comply with Indonesian regulations.

TABLE 40. RATING SCALE BETWEEN ALTERNATIVES TO REGULATORY COMPLIANCE IN PORT TANK AND TANKER TRUCK

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Tanker Truck**
		✓							✓	

Following Table 40 can be shown Port Tanks are more priority than Tank Trucks due to Compliance with Indonesian Regulations.

TABLE 41. RATING SCALE BETWEEN ALTERNATIVES TO REGULATORY COMPLIANCE IN PORT TANK AND BARGE

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Barge**
		✓					✓			

Following Table 41 can be shown Port Tank is more priority than Barge due to Compliance with Indonesian Regulations.

TABLE 42. RATING SCALE BETWEEN ALTERNATIVES TO REGULATORY COMPLIANCE IN TANKER TRUCK AND BARGE

Criterion	Priority Scale									Criterion
Tanker Truck	9	7	5	3	1	3	5	7	9	**Barge**
	✓						✓			

Following Table 42 can be shown Barge is more priority than Tanker Trucks due to Compliance with Indonesian Regulations.

3.15. Comparison Between Alternatives in Compliance with Port SOPs

The higher the value, the more you prefer and comply with the Port SOP

TABLE 43. RATING SCALE BETWEEN ALTERNATIVES IN COMPLIANCE WITH PORT SOPS IN PORT TANK AND TANKER TRUCK

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Tanker Truck**
	✓						✓			

Following Table 43 can be shown Port Tanks are more priority than Tank Trucks because of Compliance with Port SOPs.

TABLE 44. RATING SCALE BETWEEN ALTERNATIVES IN COMPLIANCE WITH PORT SOPS IN PORT TANK AND BARGE

Criterion	Priority Scale									Criterion
Port Tank	9	7	5	3	1	3	5	7	9	**Barge**
	✓							✓		

Following Table 44 can be shown Port Tank is more priority than Barge because of Compliance with Port SOP.

TABLE 45. RATING SCALE BETWEEN ALTERNATIVES IN COMPLIANCE WITH PORT SOPS IN TANKER TRUCK AND BARGE

Criterion	Priority Scale									Criterion
Tanker Truck	9	7	5	3	1	3	5	7	9	**Barge**
			✓					✓		

Following Table 45 can be shown Barge is more priority than Tanker Trucks because of its Compliance with Port SOPs.

IV. CONCLUSION

Prioritizing economical approaches over operational techniques is crucial due to their direct correlation with capital expenditure and operational costs associated with each alternative aimed at preventing marine pollution. Operational techniques, on the other hand, take precedence over safety and environmental concerns as they address the technical and operational aspects of each alternative in mitigating marine pollution. Regulations, being paramount, supersede safety and environmental considerations as they impact every alternative, encompassing both Indonesian regulations and Standard Operating Procedures (SOPs) at ports.

The priority lies in Ease of Installation over Ease of Operation/Maintenance due to the simplicity of installation or manufacturing processes associated with each alternative. Ease of Installation takes precedence over the duration of suction during ship operations owing to the simplicity of installation or manufacturing inherent in each alternative. Furthermore, Ease of Operation/Maintenance is prioritized over the duration of suction during ship operations due to the simplicity of operation/maintenance associated with each alternative.

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