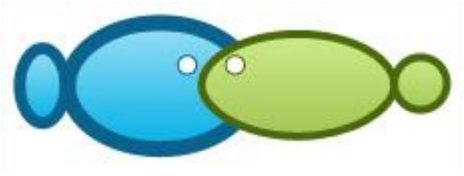

Analytical hierarchy process (AHP) analysis of maritime environmental protection strategies and priorities in Silugonggo River channel, Indonesia

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Abstract. Juwana Port is located at Silugonggo River channel which has been serving as shipping lane, port activities and ship moorings since the 18th century. Juwana Harbor facilitates vessels under 7 gross tonage (GT). Currently, the capacity of fishing vessels has been developed to reach 35 to 300 GT. The increasing activity in the Silugonggo River channel requires enchanced protection for the sustainability of the channel and waters. The preservation of the Silugonggo River channel takes precedence in safeguarding the maritime environment, encompassing all endeavors aimed at preventing and mitigating pollution stemming from vessels and shipping-related activities. This research was performed to formulate alternative strategies and priorities for maritime environmental protection in Silugonggo River channel. Analytical hierarchy process (AHP) model was employed in data analysis to determine the priority scale. The results of the analysis showed alternative strategies for the management and protection of the maritime environment that include synchronizing the roles and responsibilities of stakeholders, developing policies related to the maritime environment, monitoring the activities of community fishing enterprises, as well as the construction of anchor pools and supporting infrastructure.
Key Words: maritime environment, port, policy, river channels, sedimentation.

Introduction. As an archipelagic country, the fisheries sector plays an important role in supporting Indonesia's food security (Manullang et al 2022). The advancement of fishing vessels has significantly affected the fisheries sector, including the one along Silugonggo River in Juwana since vessels facilitate the fish trade and marine exploration (Byrnes & Dunn 2020). Rivers in Indonesia also serve shipping activities that affect the economic sustainability of the community (Aina et al 2017; Prasetiawan et al 2021). Silugonggo River channel serves as a mooring spot for ships, a docking place, and a port.

At the present, fishing vessels of less than 35 gross tonage (GT) have been upgraded or overhauled to a capacity greater than 60 GT. Meanwhile, the sizes of channel and docks remained unchanged. The average modern ship now measures 24 meters in length and 3-5 meters in width, necessitating appropriate facilities for mooring, loading, unloading, and other shipping activities. Ship's tonnage (gross tonnage/GT) is the volume of all spaces below the ship's deck and the volume of enclosed spaces above the deck (superstructure) measured based on the International Convention on Tonnage Measurement of Ships (1969) and Government Regulation of the Republic of Indonesia Number 51 of 2002 concerning shipping. Net tonnage (NT) refers to the usable volume of a ship determined based on the International Maritime Organization (1969) yet it does not show the amount, weight, capacity and volume of cargo (Ministerial Regulation No. 45 of 2021 concerning the Ship Measurements; Schwarzkopf et al 2021). Tonnage is a key indicator of a fleet's carrying capacity, adjusted for increased ship productivity

(Tenold 2019). Consequently, modern ships are built larger with more advanced operating systems and specialized crews (Hannaford & Van Hassel 2021).

Fishing vessel construction in Indonesia is under the authority of two ministries, resulting in overlapping regulations and interests. The current construction of fishing vessels must be equipped with vessel design drawings that are approved by the General Directorate of Maritime Transport. The design of the vessel referred to in Article 4 shall be made after the shipowner has determined the criteria for the type and function of the vessel, the type of cargo carried, the capacity carried, the speed of the vessel, the area of operation and the engine power based on the national regulations, international agreements, ship classification regulations, and/or developments in the latest shipping regulations and technology (Regulation of the Minister of Transportation of the Republic of Indonesia Number 54 of 2021 concerning Ratification of Ship Design Drawings, Implementation and Supervision of Ship Construction and Work).

At the present, fishing vessels have not yet fulfilled the requirements of this Regulation which include the prevention of pollution, waste management, contamination prevention, and anti-fouling. This condition inhibits entrepreneurs and fishing vessel operators from comprehending the importance of protecting the maritime environment. The increasing number of ships anchoring and ships repair activities such as engine repair, hull repair, anti-fouling, painting, and scrubbing or covering of ships pollute Silugonggo River. Those activities also make the river shallower from the deposition of waste wood from ship repair.

Ship docking activities potentially cause river pollution due to oil spills or oil leaks from ships (Darlan & Kamiludin 2008). Pollution along the Silugonggo River is exacerbated by human behavior. Inadequate infrastructure and facilities have been the major factors of these issues (Prasetiawan 2023). The most significant pollution in the Juwana River channel is caused by liquid waste in the form of diesel fuel that is difficult for organisms to decompose, leading to lower physicochemical and microbial quality of the river water (Utomo et al 2013). The condition further affects the quality of the fish since such waste make the fish taste and smells like diesel fuel.

In this research, the analytical hierarchy process (AHP) model was employed in data analysis on the Expert Choice 11 application. AHP provides preference scores through pairwise comparisons of decision problem items regarding a defined goal (Saaty 1987). AHP users first decompose the decision problem into elementary parts and then compare each pair of data points to develop a preference scale among alternatives at each level of decomposition (Spina 2016). In this case, AHP was used to determine strategies and priorities for maritime environmental protection and management of Silugonggo Juwana river channel.

Material and Method

Description of the research sites. This research was conducted on the Silugonggo River from February 2023 to November 2023 along the Silugonggo River channel from the Juwana Bridge to the estuary. This research primarily examined the integrated maritime environmental protection for ships moored in the Silugonggo River channel and port activities along an 8.5 km long river channel with a width of approximately 100 meters. The commercial port infrastructure is located at Post I with a pier length of 170 m with a mooring capacity of 20 vessels of 24 m long, 3-5 m wide. Post II has a length of 120 meters and a mooring capacity for 15 vessels, each 24 meters long and 3-5 meters wide. The fishing port, including Fish Auction Unit I and Fish Auction Unit II, as well as the commercial port pier, are all located along the banks of the Silugonggo River. Bajomulyo Beach Fishing Port is located at coordinates 111°8'30" E and 6°42'30" S, with a pier length of 100-150 m (Triyantoro et al 2021), with a Fish Auction Unit I dock area of 200 m^2 and Fish Auction Unit II dock area of 345 m^2 and a river channel depth of 10 meters (Jauhari et al 2021). Silugonggo River channel also offers ship docking facilities with a capacity of 15 ships under the ownership of Putra Usaha Barokah Corporation and Bumi Rejo Corporation with a capacity of 6 vessels. According to field data, Silugonggo

River channel can accommodate ±2000 mooring vessels from 7 to 200 GT. The map of the site is shown in Figure 1.

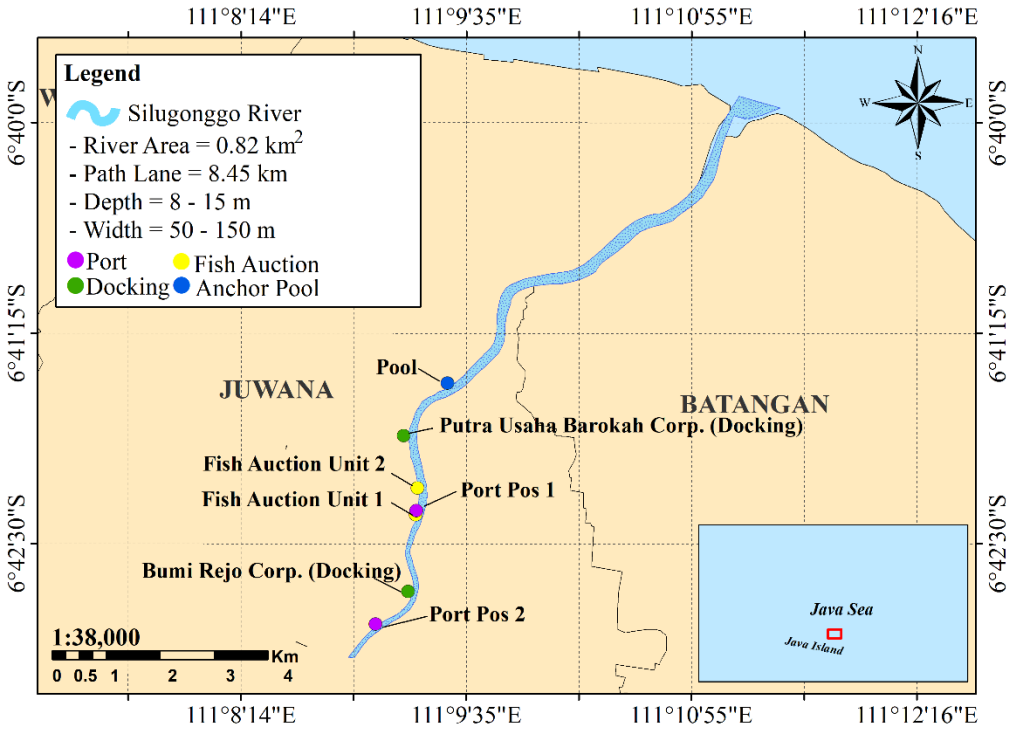

Figure 1. Silugonggo River channel research location.

Donor reef and nursery setup. This field research was performed using a descriptive analysis in the form of AHP analysis to determine the priority scale of the proposed policies or strategies. This research regarded both internal and external aspects in determining the strategies. The variables measured in the AHP were the policy, monitoring, awareness, and infrastructure in the Silugonggo River channel.

The principles of AHP are decomposition, evaluation of criteria and alternatives (comparative judgment), determination of priorities (synthesis of priorities), and logical consistency (Utomo et al 2011). These aspects are used in determining the preferences using Expert Choice 11 software. This research involved 7 respondents, consisting of the representatives of nearby community, vessel crew, fishermen or entrepreneurs, Central Office of Pemali Juwana, Class III Juwana Port Organizing Unit, the Regional Government of Pati Regency and Central Java Province who work in Bajomulyo Beach Fishing Harbor, and the Ministry of Maritime Affairs and Fisheries.

The data were then used in the formulation of policy directions for maritime environmental protection models of Silugonggo River channel. AHP simplified complex, unstructured, strategic, and dynamic problems into component parts to be arranged in a hierarchy. After that, the level of importance of each variable is assigned a numerical and subjective value based on the relative importance in comparison to other variables. The AHP criteria were set based on the ones that have significant impacts on the system to avoid excessive number of criteria. The value weighting analysis for each criterion was performed using a 9-point Likert Scale.

The criteria used to formulate a maritime protection strategy for the Silugonggo River include policy, monitoring, awareness, and infrastructure factors. The policies involve regulations governing activities around the Silugonggo River's maritime environment. It includes rules on vessel size, vessel equipment, vessel waste disposal systems, vessel mooring locations, and other relevant regulations issued by the government. The monitoring criteria is the evaluation and control activities done by the government regarding fishing and port activities along the Silugonggo River channel. Meanwhile, awareness refers to the awareness of the surrounding community regarding

the condition of the environment of the Silugonggo River channel. Finally, the infrastructure criteria refer to the completeness and availability of infrastructure such as anchor pool, waste disposal sites and other supporting infrastructure.

Results. Based on the identification of internal and external factors of the Silugonggo River channel, assessment results and opinions were gathered from various respondents, including the community, vessel crew, fisheries and port entrepreneurs, Pemali Juwana River Area Headquarters, Class III Juwana Port Organizing Unit, local government, and the Ministry of Maritime Affairs and Fisheries. The human mind organizes complex realities into main elements, which are then further divided into parts, forming a hierarchical structure (Damayanti et al 2022). The AHP assigns a relative attractiveness score to each factor. The hierarchy for determining the strength of the Silugonggo River Maritime Environmental Protection Strategy is illustrated in Figure 2.

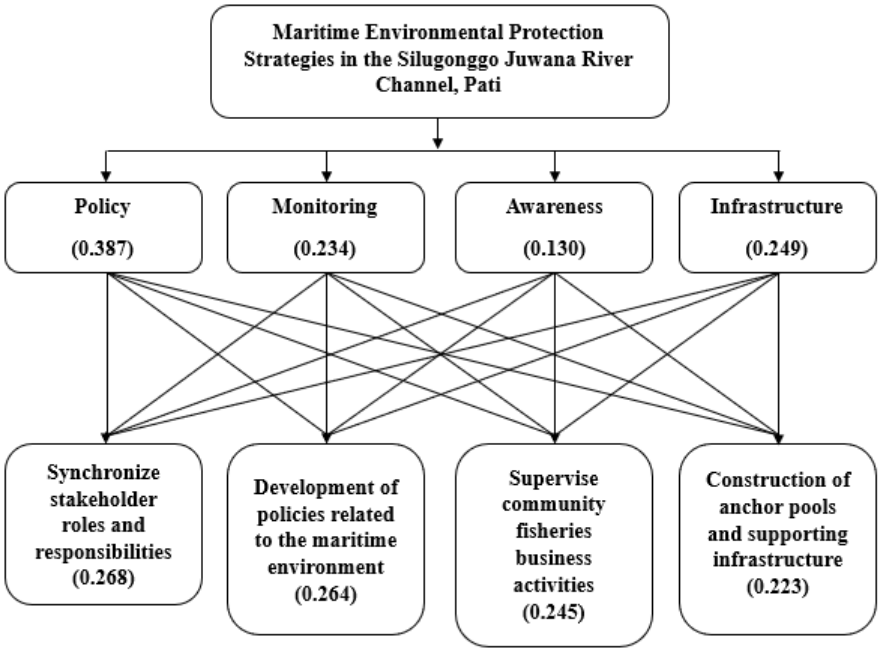

Figure 2. Analytical hierarchy process results using Expert Choice 11 software.

The strategy with the highest total relative attractiveness score shows the priority strategy. After the analysis and calculation of the Total Intermediate Score value, a quantitative maritime environmental strategy matrix was obtained. The priority weighting diagram for maritime environmental protection strategies in the Silugonggo River channel based on all the criteria considered is presented in Figure 3.

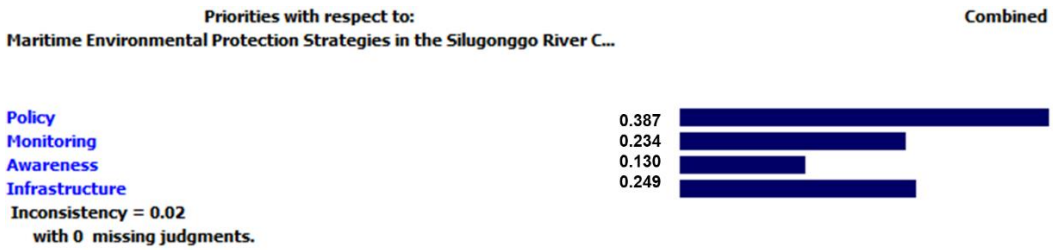

Figure 3. The priority weighting diagram.

As shown in Figure 2 and Figure 3, policy factors for the arrangement of river channels and ship moorings in accordance with Work Environment Areas and Port Environmental Areas of Interest should be taken into consideration in designing the maritime environmental protection strategies for Silugonggo River channel. The policy factor holds the highest weight of 0.387, indicating its significant influence on maritime environmental

protection strategies. Infrastructure follows closely with a weight of 0.249, highlighting its importance in shaping regulations. Monitoring, with a weight of 0.234, serves as an essential tool for evaluating regulatory progress. However, the awareness factor, with a weight of 0.130, is deemed less impactful on strategy formulation, suggesting that it presents fewer obstacles to policy-making decisions.

The best alternative for protecting the maritime environment in Silugonggo River channel is to synchronize the roles and responsibilities of stakeholders with a score of 0.268, followed by developing policies related to the maritime environment with a score of 0.264. The next priority is to monitor community fisheries activities with a score of 0.245 and construction of anchor pools and supporting infrastructure with a score of 0.223. The priority formulation from the AHP results is presented in Table 1.

Table 1

Formulation of priority strategies based on analytical hierarchy process (AHP)

No.	*Strategy alternatives*	*Score*	*Ranking*
1.	Synchronizing stakeholder roles and responsibilities	0.268	1
2.	Developing policies related to the maritime environment	0.264	2
3.	Supervising the fisheries business activities	0.245	3
4.	Constructing anchor pools and supporting infrastructure	0.223	4

Discussion. Alternative priority strategies that can be implemented include synchronizing roles and responsibilities and strengthening coordination among stakeholders, including the Ministry of Transport's Class III Juwana Port Management Unit, which is responsible for the functions of commercial ports, channel management, maritime safety and security, ship crews, and marine environmental protection. Bajomulyo Beach Fishing Port under the Maritime and Fisheries Service of Central Java Province and the Maritime and Fisheries Service of Pati Regency should optimally manage the functions of fishing port, channel management and protection of the marine environment and ship crews. Pati Regency Maritime and Fisheries Service also need to provide training to the community in the field of fisheries and maritime safety. Relevant institutions play crucial roles in promoting fishing activities. Fishing ports have to provide optimal service to fulfill the interests of the fishing community, especially the fishermen (Alfiana et al 2018) to ensure that the function of the Silugonggo River channel is maximized for the benefit of the people of Pati Regency and the buffer areas around Pati Regency. The maintenance and monitoring of Silugonggo River channel is under the responsibility of Area Headquarters of Pemali Juwana River under the Ministry of Public Works and Physical Planning. The success of this program requires cooperation from stakeholders in improving the sustainability of the river. Dredging also needs to be conducted every year, considering the absence of dredging from 2019 to 2023.

Based on the research results, it is evident that the three ministries responsible for overseeing the Silugonggo River channel still face challenges in analyzing the data. Furthermore, there is a potential for overlap in the implementation of the regulations. The Ministry of Transportation and the Maritime and Fisheries Agency of Central Java Province and the Maritime and Fisheries Agency of Pati Regency need to collaborate and align their functions, especially in regulating regulations and policies. It is also necessary to strengthen the coordination and cooperation with the Area Headquarters of Pemali Juwana River in the monitoring of the channel and the dredging. In many countries, this holistic approach is packed in the integrated marine spatial planning (Talib et al 2022).

The second priority lies in the development of policies concerning the maritime environment. The duration of vessel mooring significantly impacts the flow of river water into the estuary, thereby influencing sedimentation patterns. Maintenance of navigability in ports, rivers, and waterways necessitates dredging to eliminate sediment accumulation resulting from tides, river currents, and other factors (Kirichek et al 2022). Currently, there exists no regulation governing the duration of vessel mooring in the Silugonggo River channel. Consequently, ship owners anchor their vessels based on individual preferences and interests. Vessels docked in the Silugonggo River channel also conduct

repair and overhaul activities, contributing to pollution. Furthermore, the absence of regulations regarding ship equipment, such as waste disposal systems, underscores the lack of integrated policies and enforcement concerning vessel mooring management in the Silugonggo River channel. As a result, each overseeing entity, namely the Class III Juwana Port Organizing Unit and the Bajomulyo Beach Landing Port, employs varying criteria for determining mooring fees and supervising ship operations. Weak oversight of vessel mooring stems from jurisdictional overlaps, aligning with the conclusions of the AHP. This underscores the imperative to prioritize synchronizing roles, enhancing coordination, and clarifying stakeholder responsibilities as the first step towards effective implementation.

Policies and regulations regarding maritime environmental protection in Silugonggo River channel need to be further studied by the Ministry of Transportation and the Maritime and Fisheries Service of Central Java Province and the Maritime and Fisheries Service of Pati Regency. The development includes the establishment of general and technical policies (norms, standards, guidelines, criteria, plans and procedures, including shipping safety and security requirements and licensing) based on Law of the Republic of Indonesia Number 45 of 2009 concerning Amendments to Law Number 31 of 2004 concerning Fisheries).

The third alternative priority is enhancing the supervision of community fishing activities. The supervision of policy implementation should be improved. Control activities include the provision of direction, guidance, training, licensing, certification and technical assistance in the field of development and operation, while supervision includes the monitoring of development and operation activities to ensure compliance with legal requirements, including the implementation of corrective actions and law enforcement (Law of the Republic of Indonesia Number 45 of 2009 concerning Amendments to Law Number 31 of 2004 concerning Fisheries). Based on these findings, it is recommended to implement policies that involve constructing an anchor pool and a new pier with a jetty extending into the sea within the Working Environment Area and Port Environmental Areas of Interest under the jurisdiction of the Juwana Class III Port Organizing Office Unit. Additionally, river management policies should be developed, focusing on optimizing the suitability of the river channel, initiating ship mooring construction projects, and supervising the construction and upkeep of anchorage pools and docking facilities based on Republic of Indonesia Government Regulation Number 21 of 2010 concerning Maritime Environmental Protection and Ministerial Regulation Number 29 of 2014 concerning Prevention of Maritime Environmental Pollution.

The final priority alternative that can be implemented is the construction of anchor pools and other supporting infrastructure (Prasetiawan et al 2022; Prasetiawan 2023). The number of vessels moored in the Silugonggo River channel and the implementation of ship repair activities with dimensions of approximately 24 meters long, 3 to 5 meters wide with a transverse mooring position further narrows the width of the channel, affecting vessel traffic and inhibiting the flow of water from upstream to downstream. The construction of the dealer pool at Juwana is expected to accommodate approximately 300 vessels ranging from 30 to 200 GT.

The policy of building a new port with a jetty jutting out into the sea in the working area of Juwana port is regarded feasible in addressing the crowding of ships moored in the Silugonggo River channel. The policy can also increase the capacity of the port activities which will enhance the economy of the community in Pati Regency. Other supporting infrastructure should be built, including drainage canals, waste storage areas and public toilets. Putri et al (2020) highlighted the importance of Fishing Ports in fishery management and business.

Conclusions. Based on the research results, several maritime environment management and protection strategies should be prioritized in the Silugonggo River channel; synchronization of stakeholder roles and responsibilities, development of policies related to the maritime environment, supervision of community fishing business activities, and construction of anchor pools and supporting infrastructure.

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Conflict of interest. The authors declare that there is no conflict of interest.

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