

# *The Selection of Ship Type to Use Dual Fuelled or Gas Fuelled using Analytical Hierarchy Process: A Case Study of Indonesia Government*

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**Keywords:** Ship type, gas fueled, AHP model.

**Abstract:** Since the environment protection take into force of shipping industry, the use of gas as fuel on ship become more popular for gas fueled ship or dual fueled ship. Indonesia government took a role to protect the environment by apply the concept of green ship to use gas as fuel on ship. Supported by Indonesia as archipelago, rules and regulations and also the government policy, the use of gas as fuel will be suitable for Indonesia. The choice of an appropriate ship type as a pioneer study, to modification or new-built, is one of important issues for the government. An Analytic Hierarchy Process (AHP) model is constructed to choose the ship type. The criteria's as important factors are (A) Economy with sub-criteria's are (A1) total cost, (A2) operational cost, (A3) feasibility, (B) policy divided into three sub-criteria's (B1) suitability to master transport plan, (B2) constrains, (B3) socio-political acceptance, and criteria (C) Technical that consist of (C1) capacity, (C2) technical feasibility, (C3) performance. The AHP model prefer to choose passenger /roro as the best ship type for gas fueled ship. The preference value for passenger/roro vessel is 39.3% followed by merchant ship 34.6% and Pioneer/ *perintis* with preference value 26.1%. This result can be as references for the government to conduct a further study on gas as fuel on ship to develop a proper design while the analytical hierarchy process (AHP) model represent the most suitable ship type to conduct the related study.

## **1. Introduction**

Sustainability is the issue and the crucial challenge for Indonesia related to power sector, even though Indonesia was blessed with huge of energy resources. To maintain the energy sustainability, improve and create energy autonomy is one of the solution, also need energy management through policy and new technology [1], since the transportation and industrial sectors become the highest energy costumers [2]. While Qodri et.al [3] mentioned that Indonesia ranks at 55 from 71 countries related to energy security index that consisting of five dimensions: availability, affordability, accessibility, acceptability and efficiency which means that Indonesia's energy security is less than satisfactory and it should be improved.

Looking for Indonesia's gas industry, which has the dramatic changes during the history, the domestic demand would be doubled or tripled compare to current gas demand. To fill the gap, the policy and infrastructure of gas industry should be improved, even though Indonesia is one of the largest LNG exporters for three decades [4].

Gas as fuel become popular due to the environment issues. Many kinds of gas that could be used as fuel with different performance, and LNG is one that gives a significant improve to overall environmental performance [5], and also, LNG is proven as a commercial marine fuel [6]. Since the emission reduction technology selection has established by many researches, such as [7] which give LNG as the most suitable alternatives by using Fuzzy-MCDM method, and according to [8], LNG is the most suitable alternative fuel that was made by comparing eleven criterions.

"*Tol Laut*" concept is one of Indonesia government's vision and mission, *Nawacita*, which is to improve transportation performance, connecting the island and strengthen the nation. The concept should be supported by the energy sector, policy and also the current technology. Since the environment protection take into force of shipping industry, the use of gas as fuel on ship become more popular for gas fueled ship or dual fueled ship. Indonesia government took a role to protect the environment by apply the concept of green ship to use gas as fuel on ship. Supported by Indonesia as archipelago, rules and regulations and also the government policy, the use of gas as fuel will be suitable for Indonesia.

The green concept for maritime transport is the most suitable concept to realize *Nawacita* and fulfill the international requirement for environmental protection at once. *Nawacita* supported by many of ship types in it practice, and to get the appropriate ship type to be developed related to gas as fuel, the study was built to present and give recommendation.

## 2. Analytical Hierarchy Process (AHP)

The selection method to choose ship type that give the most suitable for dual fueled and gas fueled is Analytical Hierarchy Process (AHP). AHP is one of multi-criteria decision analysis (MCDA) that has wide range capability in maritime sector, e.g in [9] which explain the ship flag stage selection in Taiwanese ship-owner, [10] that using multi-criteria approach to choose the reference to start a new design, [11] focus on the selection process of vessels in the Norwegian maritime sector, especially in meeting present and future exhaust regulation.

Basically, AHP is general theory related to measurement. It was used to give the ratio scale from discrete or continue pairwise [12]. Analytical hierarchy process (AHP) consist of three stage, namely:

1. Decomposition

When the goal already, break down the problem into it smallest component is the next step. At this stage, the problem's level was established.

2. Pairwise comparison (comparative judgment)

Pairwise comparison is about compare of two elements for it weight for certain level. This comparison is the main point of AHP, and will influence the elements priorities. Regarding to get the best result, respondent should understand the overall compared elements. The weight score based on linguistic variables, 1 for "equally important", 3 for "weakly important", 5 for "demonstrably important", 7 for "strongly important", and 9 for "absolutely important. While value 2, 4, 6 and 8 represent the verbal judgement between the above described.

3. Synthesis from priority

Each pairwise comparison matrix should calculate the Eigen vector to produce the local priority for each level. Global priority is obtained by synthesis between local priorities.

AHP is well established by using Consistency Ratio (CR) as its parameter. The CR should not be more than 0.1, while CR is described as Consistency Index (CI) divided by Random Index (RI). RI refers to table 1 below, while CI is based on equation (1).

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (1)$$

Eigen factor ( $\lambda$ ) is obtained from the average sum for each matrix row, and  $n$  is the matrix order.

Table 1: Random index value

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

### 3. Case Study

The goal has been set, to find the most suitable ship to implement dual fuel technology for Indonesia government. The problem will break down into criteria and sub-criteria. According to the previous study related to transportation, the use of multi-criteria decision making has been widely used, and the model has been used for the assessment of road transport projects [13], selection of mode of transport and vessels [14] [15] [16] [17], and for optimization [18]. The criteria and sub-criteria were used and simplified into the most studied as mentioned in [11]. Technical, Economic, and Policy are the three criteria used in this study, while each criterion is divided into three sub-criteria.

To select the alternatives, [19] shows that the Passenger ferry vessel is the highest number of operated vessels that use gas as its fuel, while the Platform Supply Vessel (PSV) is the highest number of ordered vessels that use gas as its fuel, followed by Ro-ro and passenger ferry. Statistically, Indonesia government has Ro-ro vessel growth from 254 to 354 units from 2012 to 2016 [20], while the merchant ship, including general cargo, container, bulk carrier, and tanker, grows more than 100% from the period 2005 to 2013, passenger vessels grow 88.6% from the mentioned period. Since Indonesia is an archipelago, the Perintis / pioneer vessel grows rapidly and is expected to reach 198 units in 2019 from 95 units in 2015 [21].

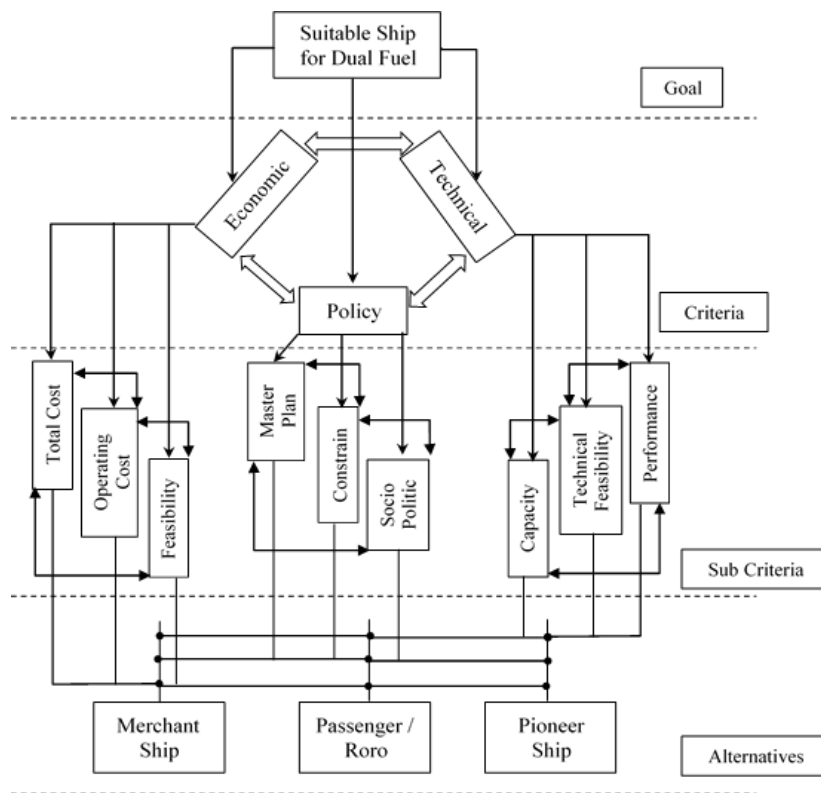


Figure 1: Hierarchy structure of ship type selection

Questionnaires were distributed that consist of pairwise comparison from each respondent. The respondents involves classification biro, academic institutional, ship-owner and operator, and other related government institution. Since these respondents have a better knowledge relating to gas fueled ship, the regulator have studied the regulation of International Code of Safety for Shipping Using Gases or Other Low-Flashpoint Fuels (IGF Code). Operator respondent has conducted the feasibility study to convert their fleet to gas fueled ship.

#### 4. Result and Discussion

##### 4.1.Judgement and Rank

The pairwise from each respondent has been collected and calculated using geo-mean method to get a single pairwise judgment for each level. The criteria level shown that “Technical” takes the highest place of weight, followed with “Economy” and the last “Policy” criteria, with the preference value, in order, 0.517, 0.289 and 0.195. The pairwise also shown that at criteria level, the Consistency Ratio (CR) is 0.095, it’s mean that the judgment well accepted to the next level, the sub-criteria level.

While the pairwise going further into sub-criteria, the local weight obtained, then the local weight also arise with other local weight. The overall judgement generate a rank for each criteria as shown below.

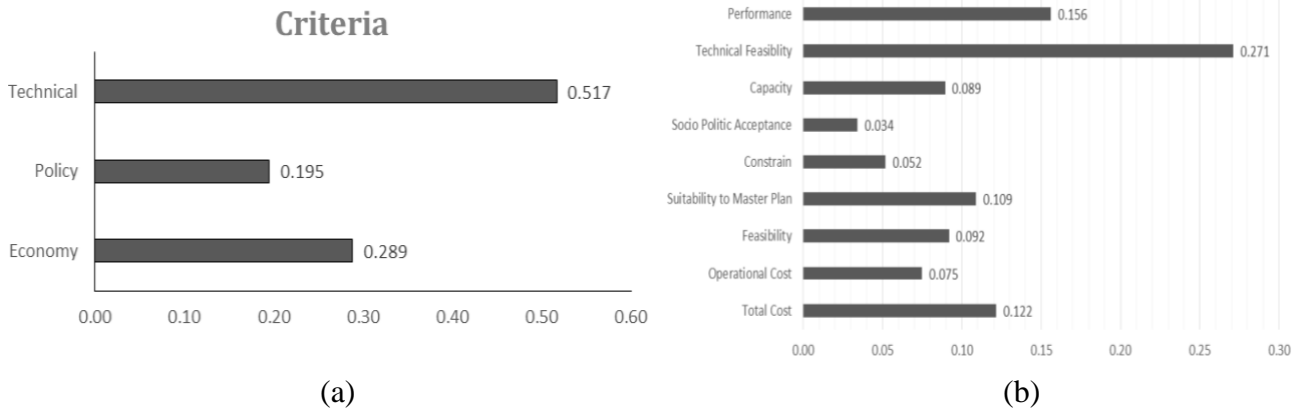


Figure 2: (a) Criteria weight (b) Sub-criteria global weight.

Global weight shown that the “Technical Feasibility” is the most important criteria to assessment the suitability for vessel type regarding to gas fueled and dual fueled, the represent value is 0.271 or about 27.1% compared from all sub-criteria. Second place for global weight is “Performance” with value 0.156 followed by “Total cost” 0.122, “Suitability with master plan” 0.109, “Feasibility” from “Economy” criteria with the value 0.092, “Capacity” 0.089, “Operational cost” 0.075, “Constrain” 0.052, and the last is “Socio politic acceptance” with value 0.034. Pairwise comparison for “Cost” criteria gives 0.011 of CR value, 0.018 CR for “Policy” and 0.005 CR for “Technical”. The CR shown that the judgment and pairwise comparison could go further to alternatives pairwise comparison.

Pairwise comparison get into the alternatives level. Table 2 summarize the result. Passenger/ro-ro type seem to be the most suitable vessel type for Indonesia government to develop as dual fueled and gas fueled vessel. Global weight for passenger/ro-ro vessel is 0.393 or about 39.3% respondent likes to choose passenger/ro-ro type as the suitable vessel to use gas as its fuel. Merchant vessel with preference value 34.6% and *Perintis/pioneer* about 26.10%.

The score of merchant vessel for “economy” is about 0.419, 0.3567 for “Policy” and 0.3011 for “Technical”. Passenger/ro-ro gives 0.3126 point for “Economy”, 0.417 for “Policy” and 0.4288 for “Technical”, while *Perintis/pioneer* has 0.2683 point for “Economy”, 0.2262 for “Policy” and 0.27 point for “Technical”, and overall as mentioned above.

Table 2: Overall weight

Criteria	Weight	Sub Criteria	Local Weight	Global Weight	Merchant Ship		Passenger/Roro		Pioneer	
					Local Weight	Global Weight	Local Weight	Global Weight	Local Weight	Global Weight
Economy	0.289	Total Cost	0.422	0.122	0.5084	0.0619	0.2018	0.0246	0.2898	0.0353
		Operational Cost	0.260	0.075	0.3146	0.0236	0.3532	0.0265	0.3322	0.0249
		Feasibility	0.318	0.092	0.3859	0.0354	0.4264	0.0392	0.1877	0.0172
Policy	0.195	Suitability to Master Plan	0.559	0.109	0.3117	0.0339	0.4535	0.0494	0.2348	0.0256
		Constrain	0.265	0.052	0.4681	0.0242	0.3100	0.0160	0.2219	0.0115
		Socio Politic Acceptance	0.176	0.034	0.3317	0.0114	0.4627	0.0159	0.2055	0.0070
Technical	0.517	Capacity	0.173	0.089	0.1940	0.0173	0.5777	0.0516	0.2283	0.0204
		Technical Feasibility	0.525	0.271	0.2958	0.0802	0.4569	0.1239	0.2473	0.0670
		Performance	0.302	0.156	0.3716	0.0580	0.2951	0.0461	0.3333	0.0521
Overall					0.3460		0.3930		0.2610	

#### 4.2.Sensitivity Analysis

Sensitivity analysis was conducted to check the flexibility of the result. Changing the weight for each criteria into different value, compare with the original weight then check the final selected alternative. Figures below shown the sensitivity analysis that vary the criteria value. Sensitivity analysis #1 by changing the Economy, Policy and Technical criteria into value 0.25, 0.25 and 0.5 respectively. Sensitivity analysis #2 change the value Economy into 0.25, Policy into 0.5 while Technical into 0.5, while Sensitivity analysis #3 change the value Economy into 0.5, Policy into 0.25 and Technical value into 0.25, in contrary, Sensitivity analysis #4 gives Economy, Policy and Technical equal value, 0.333 represent one third value.

Sensitivity analysis shown that the origin result keep in the place, the Passenger/roto vessel as the most suitable vessel regarding to gas fueled and dual fueled. The origin value for passenger/roto vessel is 39.3%, increase into 39.7% for sensitivity analysis #1, 39.3% at sensitivity analysis #2 and decrease a little for sensitivity analysis #4 at 38.6%, and also the above sensitivity analysis did not change the order of alternative's weight.

Sensitivity analysis #3 as shown in Fig.7 the order of alternatives weight changes, the highest value for merchant ship about 37.4%, following by passenger/Roro 36.8% and perintis/pioneer ship for 25.8%. The sensitivity analysis #3 give a little difference between merchant ship's weight and passenger/roto's weight. The original value for merchant ship is 34.6%, 39.3% for passenger/roto and 26.1% for perintis/pioneer ship. It shown that the merchant ship takes more value in Economy criteria since this criteria increased into 0.5 from the origin value 0.313.

#### 5. Conclusion

The utilize gas as fuel become more popular and more environmental friendly for marine issues. Supported by huge gas resources, Indonesia should develop the technology and also exploit the use of gas as fuel. The study present the choosing process of ship type regarding to gas fueled and dual fueled vessel, that include three criteria and nine sub-criteria, facing the three alternatives. The result shown that the Passenger/roto vessel is the most suitable vessel developed for the use of gas as its fuel.

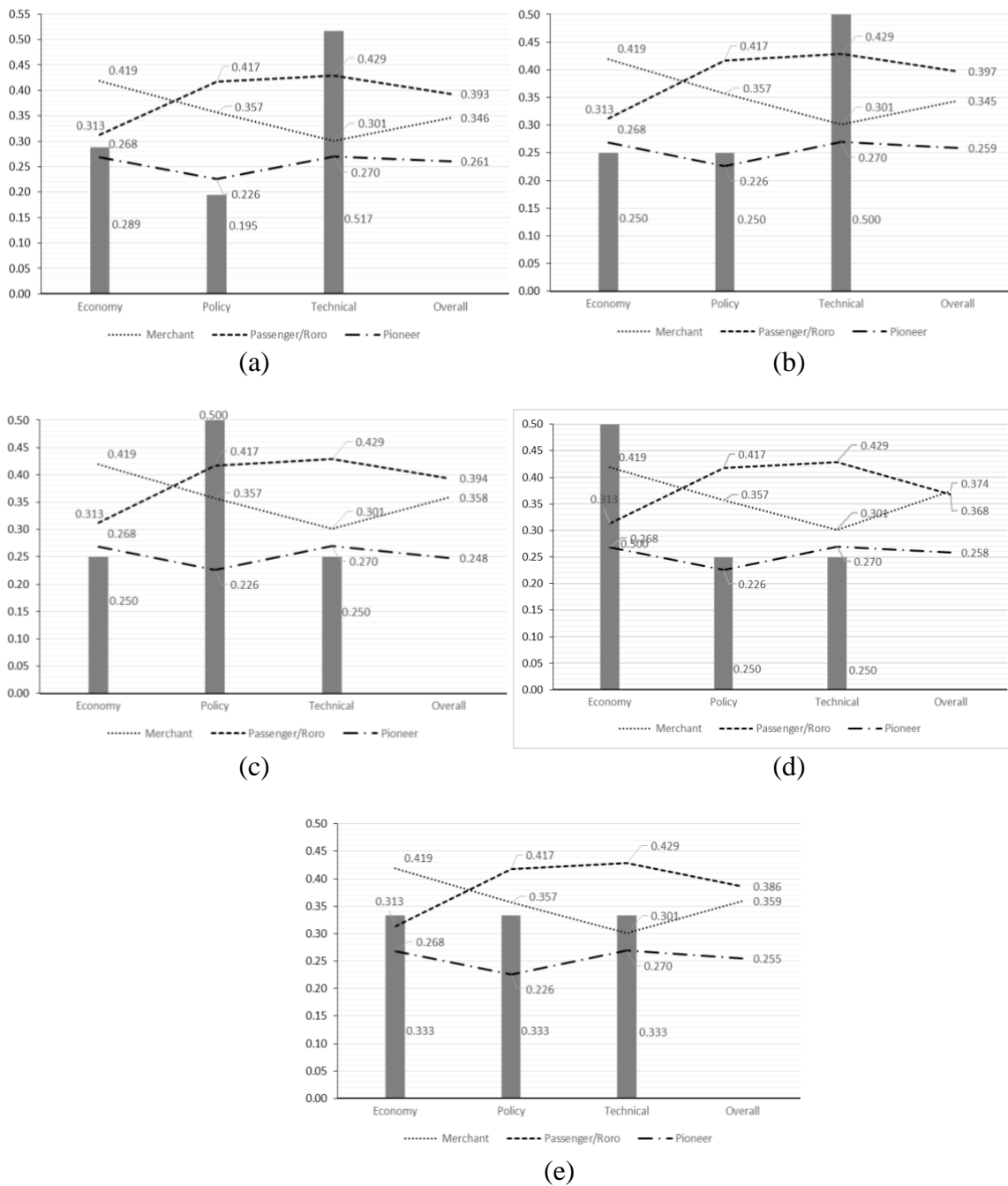


Figure 3: (a) Overall weight original (b) overall weight (sensitivity analysis #1) (c) overall weight (sensitivity analysis #2) (d) overall weight (sensitivity analysis #3) (e) overall weight (sensitivity analysis #4)

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