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Application Of a Combination of AHP and TOPSIS Methods in Shipyard Selection

Iman Taufiq Daulay[1], A.A.B. Dinariyana[2]
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Abstract - Choosing a shipyard that does not meet the requirements can affect ship building process. Incompatibility of construction process can cause delays in completion time or delivery of ship to shipowner. The resulting delays can affect reputation of shipowner because they cannot fulfill their cargo delivery services, where cargo contract is generally carried out before ship is handed over from shipyard to shipowner. Delays will also affect insurance providers, both ship and cargo insurance. A stricter evaluation from insurance company could result in an increase in premiums charged due to risks that will be faced in the future. The aim is to determine priority of shipyards that will be appointed for ship construction in Batam area. Because shipyard selection does not only involve quantitative but also qualitative variables, Multi-Criteria Decision Making (MCDM) method was used in this research. Method used in selection is a combination of Analytical Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). AHP is used to determine weight of the criteria and sub-criteria used in selection, while TOPSIS is used to determine shipyard selection priorities based on weight of criteria and sub-criteria that have been generated from AHP process. Respondents in this study were representatives of three ship owners, consisting of two technical managers and one deputy general manager. Based on the results of the analysis of six shipyards in Batam area, a priority order of shipyards recommended for ship construction by company was obtained. Sensitivity analysis also shows that the results produced in shipyard selection are quite robust.

Keywords: *Shipyard Selection, MCDM, AHP-TOPSIS*

I. INTRODUCTION

According to [1], the maritime industry involves a large number of interrelated partners, each involved in manufacturing or distribution activities, thus forming a "maritime supply chain". The main components of this chain are shipowners and shipyards; both were involved in ship repair and building. When choosing a shipyard, ship owners must consider various parameters [2]. The Multi-Criteria Decision Making (MCDM) method is recommended to help make important decisions that cannot be determined directly [3]. The basic principle of MCDM is that decisions must be made based on several criteria [4], as intended by [3]. In this study, the criteria that need to be considered by shipowners are identified and the impact of these criteria on the appropriate shipyard selection process is determined. For this study, the Analytical Hierarchy Process (AHP) methodology by (Saaty and Vargas, 2012) and the Technique Order Preference by Similarity to an Ideal Solution (TOPSIS) by Hwang and Yoon, 1981 or a combination of both were used. The AHP and TOPSIS methods as well as a combination of the two have been applied in various fields, including supplier selection in the manufacturing industry [5], shipbuilding industry [6] and [2], container terminals [7], supply chains in the industrial world [8]; [9], machine selection [10], management [11];[12], business development [13], customer evaluation [14], business [15], strategic management [16]. For the reasons mentioned above, in this research the Batam area, Riau Islands was chosen to determine the appropriate criteria required by shipyards in obtaining projects for both ship construction and ship repair. Determining these criteria uses a combination of two methods in MCDM, namely AHP and TOPSIS. The reason for choosing the Batam area is because more shipbuilding companies are adopting facilities and systems that are widely used by international shipyards and many ships use services from shipyards in Batam in accordance with the standards required by ship owners. Apart from that, the shipyards in Batam have more varied sizes, up to 400 meters. This research considers all shipyards that have graving dock, floating dock and synchro-lift facilities including all kinds of tools as well as all types of ships with sizes that can be accommodated by the shipyard facilities. A ship owner's failure to choose a shipyard that meets existing requirements can affect the ship's operations when used to fulfill the employer's contract. This will cause delays in delivery/completion time so that the ship owner's reputation will be evaluated by the employer. Apart from that, insurance providers, both ship and cargo insurance, will carry out strict evaluations and increase premiums due to the risks they will face in the future.

Based on the differences in criteria desired by ship owners and the variations in criteria possessed by each shipyard, to make a decision based on these plural criteria, which are not certain to be possessed by each shipyard and which are desired by each ship owner, the method is used. MCDM with a combination of applying

Iman Taufiq Daulay, Study Program of Technology Management, School of Interdisciplinary Management and Technology, Institut Teknologi Sepuluh Nopember, Kampus ITS Cokroaminoto, Surabaya 60264 daulayiman@gmail.com

A.A.B. Dinariyana, Department of Marine Engineering, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember, Kampus ITS Sukolilo, Surabaya 60111

the AHP and TOPSIS methods. The AHP method is used to process subjective assessment data from the ship owner team so that the weight of each proposed criterion is obtained. Meanwhile, the TOPSIS method is used to determine which criteria have the most dominant influence on shipyard selection. Next, calculations are carried out to ensure that the priority order for the selected shipyards is a robust result through sensitivity analysis.

The merits of the TOPSIS technique, according to [17], include a sound logic that represents reasonable human decision, a straightforward computing procedure that can be quickly coded into a spreadsheet, and a scalar value that simultaneously considers the best and worst options. [9] states that the criteria and alternatives received through surveys from consumers will be gathered and computed using Super Decision software, and then using the AHP technique, a pairwise comparison matrix will be generated and priority weights for the criteria will be determined. The maximal eigenvalue, consistency index, and consistency ratio will be determined in order to determine the consistency of this matrix. If the consistency ratio is smaller than 0.1, then, in Saaty's opinion, we can say that the matrix is consistent. The TOPSIS technique will be utilized for alternative assessment after determining the criteria weights. Due to this, a decision matrix for alternatives is first created by considering the criteria, after which a normalized decision matrix will be generated. It will then calculate the weighted normalized decision matrix. [8] claims that the time commitment and complexity of the AHP coupled with TOPSIS approach are its drawbacks.

The research area, according to [6], was in Iskenderun, Turkey. Geographic Information Systems (GIS) were used to design a strategy for identifying potential locations for shipyards. The Raster Calculation (RC) approach is used to help the decision-making process. Location determination criteria are prioritized using one of the multi-criteria decision-making procedures known as AHP. As a consequence, a thematic map was made, and Iskenderun Bay's potential and best locations for shipyard investment were suggested. It has been discovered that the chosen location is already mainly operating as a port, which amply supports the validity of the study's conclusions.

A shipyard, in accordance with [19], seeks to be a location where ships are serviced, maintained and constructed based on the owner's requirements. The weight of the ships served determines which facilities are accessible in the Maluku area. Because there are long lines of ships waiting to dock in Maluku province due to the dearth of shipyards that do ship maintenance and repairs, many businesses must opt to dock elsewhere. Because it is less expensive and more adaptable when moved than traditional dock building, the floating dock system was chosen as a solution to the issue of insufficient ship docking facilities in the Maluku region. The purpose of this work is to examine the factors that affect floating dock building and choose the ideal location for dock construction in Maluku. Fuzzy AHP-TOPSIS is one of the two approaches combined in this study. Floating dock building feasibility factors, which include meteorological, geography, oceanography, environment, population, economics, and amenities and infrastructure, are ranked according to significance using FAHP. [5] states that a successful supplier selection procedure is essential to the success of any manufacturing business in the highly competitive climate of today. A multi-criteria problem, supplier selection involves both qualitative and quantitative aspects (criteria). For the purpose of handling supplier selection and evaluation, numerous models and methods have been developed. The purpose of this study is to provide a TOPSIS-based technique for assessing suppliers throughout the supply chain cycle. A numerical example is suggested to clarify the methodology and show how successful the TOPSIS approach is. [10] asserts that choosing the best machine is crucial in the contemporary economy in order to boost output and raise income. Companies need to identify the best path that results in a productive atmosphere if they want to survive in the global business climate. The more options there are and the more criteria there are, the more difficult machine selection gets. This study's machine assessment research led to the creation of a decision-support system. Using an integrated AHP & TOPSIS methodology, this framework will serve as a guide for decision-makers to choose the suitable equipment. The research's proposed methodology essentially entails two parts. The current problem criteria are analyzed and identified in the initial stage, after which the weight of the sectors and sub-sectors discovered using AHP is decided. The second phase uses TOPSIS to rank the eligible choices. It is shown how this process may be used to solve a real-world issue.

The different partners that make up the supply chain in the building business join together to accomplish a single project, claims [8]. Businesses that can successfully manage their supply networks will outperform the global market. Due to the fact that building materials account for more than 50% of the entire project expenditures, suppliers are an important part of the supply chain. Therefore, selecting the appropriate supplier is a crucial strategic choice that has to be well stated. Additionally, a variety of factors affecting supply chain management are investigated, and the impact of these factors in supplier selection is investigated using a questionnaire survey. Numerous elements that are significant in supplier selection in the construction sector are also researched based on the RRI values. It is possible to evaluate the effects of multi-criteria decision-making while selecting suppliers and employing the TOPSIS technique coupled with AHP in a real-world workplace. The study's conclusions indicate that combining the TOPSIS method with AHP is a successful method for selecting the best raw material suppliers for a certain

construction project based on organizational requirements or priority standards.

In accordance with [7], there is a lot of traffic at both quayside and landside container ports as a result of the increased usage of containers in marine trade across the world. To further clarify this matter, terminal operators are required to install the most effective operating system in their terminals. This research examines the MADM concept to determine which of three potential options—the Straddle Carrier (SC), Rail Mounted Gantry Crane (RMG), and Rubber Tyred Gantry Crane (RTG)—will be the most effective yard gantry crane at maritime container ports. In this study, the techniques for order preference by simulation to an ideal solution (TOPSIS) and the analytical hierarchy process (AHP) were employed as decision-making methods. The outcomes of the AHP and TOPSIS approaches are also fairly compared in this research.

With the background that has been mentioned, this research aims to first determine the criteria and sub-criteria to be considered in selecting a shipyard by involving experts/academics, secondly determine the weight of the criteria and sub-criteria for selecting shipyards using the AHP method, thirdly determine the order The selection of shipyards refers to the weight of criteria and sub-criteria that have been previously generated using the TOPSIS method. Fourth, carry out a sensitivity analysis to ensure that the selected shipyards are a robust shipyard selection sequence.

The benefits of this research are first from the academic side to apply an academic approach in solving practical problems in the industrial environment, especially related to the selection of shipyards in carrying out ship construction and maintenance. Second, from the practical and business side, to produce an analysis of the optimal selection of shipyards for ship repairs from ship owners so that it can be used as input for policy makers in preparing budgets related to ship repairs. From the Commercial side, the results of this calculation are very helpful in terms of improving the shipyard's bargaining position against other shipyards and becomes input to top management for continuous improvements and improvements in various aspects. From the local government side, the results of this calculation are very helpful in terms of providing public facilities that support the shipbuilding industry in the area.

II. Method

In this research, a very comprehensive application of the AHP method was implemented. By using AHP, we will obtain a pairwise comparison of the relative importance of the criteria and calculate the priority or weight of the criteria in selecting the best shipyard. The weighting in AHP is obtained using Super Decision software. The Preference Order technique based on the TOPSIS method is also applied to rank the best shipyards.

The selection criteria and sub-criteria in this research were developed based on literature studies and selection criteria applicable in the practical world of shipbuilding and then evaluated and selected through a survey of representatives of ship owners.

2.1 Selection, Questionnaire/Survey, Data Processing, Data Analysis and Determining Of Experts and Decision Makers, Criteria And Sub-Criteria

Respondents for this research were representatives of 3 ship owners who were selected to fill out this research questionnaire. All appointed representatives of shipowners have more than ten years of work experience in ship repair from the shipowner's side. The representatives of the ship owners consist of: one deputy general manager and two engineering managers.

Secondary data sources for the data required for this research come from literature studies, previous experience, shipyard evaluation and selection practices that apply in ship owning companies. To develop reliable and valid research, the shipyard selection criteria and sub-criteria were assessed and revised to meet their validity, clarity, completeness, relevance and applicability. As a result of this arbitration or survey, Table 1 summarizes the main shipyard selection criteria and sub-criteria that will be used in this research.

TABLE 1
CRITERIA, SUB-CRITERIA AND ALTERNATIVES

Criteria	Sub-Criteria	Alternatives
Production	Completion Time	PT. Pax Ocean Shipyard
	Quality	PT. ASL Shipyard
Commercial	Price	PT. Marcopolo Shipyard
Purchasing	Material Ease	PT. Batamec
Shipyard Equipment Facilities	Completeness of Shipyard Equipment	PT. Bandar Abadi
	Floating Dock/Graving Dock facilities	PT. Citra Shipyard
Human Resources	Local Labor	
	Expatriate	
Certification	Quality Certificate	
	Safety Certificate	
Working capital/Financial support	Cash	
	Bank	
Experience/Portfolio	Merchant ship	
	Warship	
Supply chain network	Batam Area	
	Indonesia Area	
	Singapore Area	
	International Area	

The rating scale is necessary for direct assessment by people involved with shipyard selection to obtain a total score for each shipyard. The respondents who will fill out this questionnaire are the same respondents who filled out the AHP questionnaire. Qualitative assessment was carried out against all developed criteria. Using this approach, a questionnaire was designed and eight alternative shipyards were taken from the list of shipyards in Indonesia.

The first step, analyze the weight of each criterion and sub-criteria using the AHP method. Super Decision software based on AHP will be used for this AHP analysis with the aim of avoiding excessive manual calculations.

The second step, make preferences for each indicator criterion or sub-criteria for the eight alternative shipyards. The weight of the AHP results for the criteria and sub-criteria is used to determine the best alternative from the shipyard.

This stage is a stage for processing and analyzing data from data processing and discussions that will be carried out on the results obtained from AHP calculations and calculating preferences for alternatives to develop criteria that influence the selection of shipyards and to choose the best shipyard.

The AHP method in this research is used to: determine which criteria and sub-criteria are more important to use as factors in decision making and determine the weight of each of these factors. A larger weight indicates that a factor is more important than other factors. These factors will be used for calculations using the TOPSIS method.

2.2 Determining Alternative Rankings using the TOPSIS

Next, the AHP calculation results will be integrated with validated secondary data to compile a decision matrix according to the TOPSIS method. The use of the TOSPIS method in this research aims to rank all alternative shipyard selection based on relative proximity to the ideal solution. The TOPSIS method was chosen because the process is simple and in accordance with existing data. The calculation results of the TOPSIS method are alternatives that have been ranked according to the factors in the AHP. In other words, the selection of shipyards can be prioritized based on the results of these calculations.

2.3 Sensitivity Analysis

Sensitivity analysis is used to ensure that the selected shipyard alternative is the most robust option, where the choice does not change much with changes in the weight of the criteria used in the selection. Scenario selection in carrying out sensitivity analysis is by making changes to several criteria that have the highest weight compared to other criteria.

III. Results and Discussion

3.1 Data Analysis of Questionnaire Results

Respondents are experts selected to answer questions from the questionnaire to find the weighting results of the predetermined criteria and sub-criteria. The selected respondents were employees in different shipping companies who had carried out ship repair or construction work at one or more shipyards in Batam.

TABEL 2
FINAL PRIORITY WEIGHT FOR EACH CRITERIA

Name	Normalized By Cluster
Criteria	
Commercial	0.1353
Shipyard Equipment Facilities	0.1249
Supply Chain Network	0.11128
Working capital/Financial support	0.12638
Experience/Portfolio	0.11304
Production	0.12967
Purchasing	0.05939
Human Resources	0.11566
Certification	0.08437

The results of validating the criteria/sub-criteria from all respondents were concluded as the final criteria/sub-criteria determined for this research.

3.2 Supermatrix Creation

Previously, calculations had been carried out to obtain criteria weights, sub-criteria weights and alternative weights. Criteria and sub-criteria weights are obtained from pairwise comparisons of the questionnaire/opinions of respondents through the questionnaire. The priority weight data for criteria, sub-criteria and alternatives is then entered into the Super Decision software used in this research. In the Super Decision software there is a "Questionnaire" option to enter weight data for criteria, sub-criteria and alternatives based on the questionnaire.

Based on the AHP method that has been carried out, Table 2 shows that there are weights for each criterion. Where the weight criteria are Commercial (0.13530), Shipyard Equipment Facilities (0.12490), Supply Chain Network (0.11128), Working Capital/Financial Support (0.12638),

Experience/Portfolio (0.11304), Production (0.12967), Purchasing (0.05939), HR (0.11566) and Certification (0.08437), with the highest ranking on Commercial criteria.

Table 3 shows that each sub-criterion in the Commercial criteria has a final weight, including: Price (0.13530), the Shipyard Equipment Facilities criteria has the final weight: Floating Dock/Graving Dock Facilities (0.09992) and Completeness of Shipyard Equipment (0.02498), with the highest ranking being the Floating Dock/Graving Facilities sub-criteria, the Supply Chain Network criteria has a final weight: Batam Area (0.05090), Indonesia Area (0.03652), International Area (0.01605) and Singapore Area (0.00781), with the highest ranking in the Batam Area sub-criteria, the Working capital/Financial support criteria has a final weight: Bank (0.06319) and Cash (0.06319), the Experience/Portfolio criterion has a final weight: Merchant Ship (0.09689) and Warship (0.01615), with the highest ranking being the Merchant Ship sub-criterion, the Production criteria has a final weight: Quality (0.06484) and Completion Time (0.06484), the Purchasing criteria has a final weight: Material Ease (0.05939), the HR criteria has a final weight: Expatriate (0.07711) and Local Labors (0.03855), with the highest ranking for the Expatriate sub-criterion, the Certification criteria has a final weight: Safety Certificate (0.04218) and Quality Certificate (0.04218).

TABEL 3
FINAL PRIORITY WEIGHT OF EACH SUB-CRITERIA

Name	Normalized By Cluster
Sub-Criteria	
Price	0.1353
Floating Dock/Graving Dock facilities	0.09992
Completeness of Shipyard Equipment	0.02498
Batam Area	0.0509
Indonesia Area	0.03652
International Area	0.01605
Singapore Area	0.00781
Bank	0.06319
Cash	0.06319
Merchant Ship	0.09689
Warship	0.01615
Quality	0.06484
Completion Time	0.06484
Material Ease	0.05939
Expatriate	0.07711
Local Labor	0.03855
Safety Certificate	0.04218
Quality Certificate	0.04218

3.3 Selection of Alternative Shipyards using the TOPSIS Method

The results of the AHP method weighting values are then used in calculations to obtain the order of the 6 alternative shipyards selected. TOPSIS method calculations using MS. Excel uses input data in the form of weights of criteria, sub-criteria and alternatives obtained from interviews with employees at shipping companies. The following is a summary of the data used in the TOPSIS calculation as shown in Table 4.

TABEL 4
VALUES GIVEN BY RESPONDENTS TO EACH CRITERIA

Shipyard	Production	Commercial	Purchasing	Shipyard Equipment Facilities	Human Resources	Certification	Working capital/ Financial support	Experience/ Portfolio	Supply Chain Network
PT. Pax Ocean	9,0	3,0	7,0	9,0	9,0	9,0	9,0	9,0	9,0
PT. ASL	9,0	5,0	7,0	9,0	9,0	7,0	9,0	9,0	9,0
PT. Marcopolo	5,0	3,0	5,0	7,0	7,0	5,0	5,0	7,0	7,0
PT. Batamec	3,0	7,0	5,0	5,0	7,0	7,0	7,0	7,0	7,0
PT. Bandar Abadi	3,0	7,0	5,0	5,0	5,0	3,0	5,0	5,0	5,0
PT. Citra Shipyard	7,0	9,0	5,0	7,0	5,0	7,0	7,0	7,0	7,0
	Benefit	Benefit	Benefit	Benefit	Benefit	Benefit	Benefit	Benefit	Benefit
	0,12967	0,13530	0,05939	0,12490	0,11566	0,08437	0,12638	0,11304	0,11128

There are several steps used in calculating TOPSIS. The steps used are as follows:

1. Determine the Normalized Decision Matrix (Normalized Decision Matrix)

Table 5 shows the normalized decision matrix and Table 6 is a weighted normalized matrix resulting from multiplying the normalized matrix with the criteria weights resulting from AHP.

TABEL 5
NORMALIZED DECISION MATRIX

Shipyard	Production	Commercial	Purchasing	Shipyard Equipment Facilities	Human Resources	Certification	Working capital/ Financial support	Experience/ Portfolio	Supply Chain Network
PT. Pax Ocean	0.565	0.201	0.497	0.511	0.511	0.556	0.511	0.492	0.492
PT. ASL	0.565	0.336	0.497	0.511	0.511	0.432	0.511	0.492	0.492
PT. Marcopolo	0.314	0.201	0.355	0.398	0.398	0.309	0.284	0.383	0.383
PT. Batamec	0.188	0.470	0.355	0.284	0.398	0.432	0.398	0.383	0.383
PT. Bandar Abadi	0.188	0.470	0.355	0.284	0.284	0.185	0.284	0.274	0.274
PT. Citra Shipyard	0.439	0.604	0.355	0.398	0.284	0.432	0.398	0.383	0.383

TABEL 6
WEIGHTED NORMALIZED DECISION MATRIX

Shipyard	Production	Commercial	Purchasing	Shipyard Equipment Facilities	Human Resources	Certification	Working capital/ Financial support	Experience/ Portfolio	Supply Chain Network
PT. Pax Ocean	0.073	0.027	0.030	0.064	0.059	0.047	0.065	0.056	0.055
PT. ASL	0.073	0.045	0.030	0.064	0.059	0.036	0.065	0.056	0.055
PT. Marcopolo	0.041	0.027	0.021	0.050	0.046	0.026	0.036	0.043	0.043
PT. Batamec	0.024	0.064	0.021	0.035	0.046	0.036	0.050	0.043	0.043
PT. Bandar Abadi	0.024	0.064	0.021	0.035	0.033	0.016	0.036	0.031	0.030
PT. Citra Shipyard	0.057	0.082	0.021	0.050	0.033	0.036	0.050	0.043	0.043

2. Calculating Positive Ideal Solutions (A+) and Negative Ideal Solutions (A-)

The values in the ideal solution matrix are given in Table 7.

TABLE 7
POSITIVE IDEAL SOLUTIONS AND NEGATIVE IDEAL SOLUTIONS

Attribute	Max	Max	Max	Max	Max	Max	Max	Max	Max
Ideal Positive (A')	0.073	0.082	0.030	0.064	0.059	0.047	0.065	0.056	0.055
Ideal Negative (A)	0.024	0.027	0.021	0.035	0.033	0.016	0.036	0.031	0.030

3. Calculating the Distance between Positive Ideal Solutions (D+) and Negative Ideal Solutions(D-)

The calculation results can be seen in Table 8.

TABLE 8
SOLUTION DISTANCE TO POSITIVE AND NEGATIVE IDEAL VALUES

Criteria	PT. Pax Ocean	PT. ASL	PT. Marcopolo	PT. Batamec	PT. Bandar Abadi	PT. Citra Shipyard
Distance to Ideal Positive (D+)	0,054	0,038	0,078	0,066	0,085	0,043
Distance to Ideal Negative (D-)	0,083	0,082	0,032	0,049	0,036	0,072

4. Calculating Preference/Relative Closeness of Alternatives and Ranking

The relative preference/closeness of each alternative can be calculated by dividing the Positive Ideal Solution Distance (D+) value for each alternative by the sum of the Positive Ideal Solution Distance (D+) and Negative Ideal Solution Distance (D-) for each alternative. The calculation results can be seen in Table 9.

TABLE 9
RELATIVE PREFERENCE/CLOSENESS RELATIF

Alternative	Preference Value	Best Choice	Worst Choice	Rank
PT. Pax Ocean	0,605	-	-	3
PT. ASL	0,685	PT ASL	-	1
PT. Marcopolo	0,294	-	PT. Marcopolo	6
PT. Batamec	0,427	-	-	4
PT. Bandar Abadi	0,298	-	-	5
PT. Citra Shipyard	0,626	-	-	2

Based on the selection procedure carried out using the TOPSIS method, choices are obtained based on the selection criteria used. The best shipyard choice is PT. ASL which was followed by PT Citra Shipyard, PT. Pax Ocean, PT. Batamec, PT. Bandar Abadi, and the last one is PT. Marcopolo. To find out whether the resulting choice is the best choice, a sensitivity analysis will be carried out to evaluate changes in the weight of each criterion. The next part of this research provides six criteria weight change scenarios to test the selection results of alternative shipyards.

3.4 Sensitivity Analysis

Six criteria weight change scenarios were considered in this study. The scenario is given based on the dominant criteria, namely the five criteria that have the highest weight of the nine criteria used in the selection. The scenarios used in this sensitivity analysis are given in Table 10.

TABLE 10
SCENARIO WEIGHTS FOR CRITERIA SELECTION

Criteria	**Base Case**	**Preference Weight Increment (%)**				
		Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
		Portfolio (20%)	**Supply Chain Network (20%)**	**Production (20%)**	**Facility (20%)**	**Commercial (20%)**
Production	0.130	0.127	0.127	0.156	0.127	0.126
Commercial	0.135	0.132	0.133	0.132	0.132	0.162
Purchasing	0.059	0.057	0.057	0.056	0.056	0.056
Shipyard Equipment Facilities	0.125	0.122	0.122	0.122	0.150	0.122
Human Resources	0.116	0.113	0.113	0.112	0.113	0.112
Certification	0.084	0.082	0.082	0.081	0.081	0.081
Working capital/ Financial support	0.126	0.124	0.124	0.123	0.123	0.123
Experience/ Portfolio	0.113	0.136	0.110	0.110	0.110	0.110
Supply Chain Network	0.111	0.108	0.134	0.108	0.108	0.108

Based on Table 10, the scenarios used are (1) portfolio weight increased by 20%; (2) the weight of the supply chain network is increased by 20%; (3) production weight increased by 20%; (4) weight of shipyard facilities increased by 20%; and (5) commercial weight increased by 20%. The values in the table represent changes in each criteria weight as a result of an increase in the preference weight.

The results of selecting alternative shipyards using TOPSIS for Scenarios 1 to Scenario 5 can be seen in Table 11. Based on the selection results, it appears that a 20% increase in portfolio weight, supply chain network and shipyard facilities will not change the selectability of PT. ASL as the best alternative shipyard. The selection results are the same as those produced if no changes were made to the criteria weights produced from the AHP. However, in the condition that the commercial weight is increased by 20%, which means that commercial is the main weight in the selection, the shipyard that is the main choice is PT. Shipyard image. However, in practice, it is very rare for shipyards to offer ship building prices with a very large difference. Thus, it can be concluded that the results of the selection made produced a robust choice.

TABLE 11
RESULTS OF SENSITIVITY ANALYSIS FOR SHIPYARD SELECTION

		Selected Shipyard dan Preference Value					
		Rank 1	**Rank 2**	**Rank 3**	**Rank 4**	**Rank 5**	**Rank 6**
Base Case		PT. ASL Shipyard	PT. Citra Shipyard	PT. Pax Ocean Shipyard	PT. Batamec	PT. Bandar Abadi	PT. Marcopolo
		0,685	0,626	0,605	0,427	0,298	0,294
Scenario 1	Portfolio (20%)	PT. ASL Shipyard	PT. Citra Shipyard	PT. Pax Ocean Shipyard	PT. Batamec	PT. Marcopolo	PT. Bandar Abadi
		0,689	0,624	0,609	0,429	0,300	0,295
Scenario 2	Supply Chain Network (20%)	PT. ASL Shipyard	PT. Citra Shipyard	PT. Pax Ocean Shipyard	PT. Batamec	PT. Marcopolo	PT. Bandar Abadi
		0,689	0,624	0,609	0,429	0,300	0,295
Scenario 3	Production (20%)	PT. ASL Shipyard	PT. Citra Shipyard	PT. Pax Ocean Shipyard	PT. Batamec	PT. Marcopolo	PT. Bandar Abadi
		0,702	0,630	0,623	0,397	0,298	0,283
Scenario 4	Facility (20%)	PT. ASL Shipyard	PT. Citra Shipyard	PT. Pax Ocean Shipyard	PT. Batamec	PT. Marcopolo	PT. Bandar Abadi
		0,691	0,623	0,611	0,416	0,302	0,294
Scenario 5	Commercial (20%)	PT. Citra Shipyard	PT. ASL Shipyard	PT. Pax Ocean Shipyard	PT. Batamec	PT. Bandar Abadi	PT. Marcopolo
		0,657	0,644	0,553	0,453	0,342	0,271

IV. Conclusion

Based on intensive literature study and input from experts through distributed questionnaires, nine criteria and eighteen sub-criteria were obtained which are believed to influence the selection of shipyards in the Batam Region.

Using the AHP method, the highest criteria weight in selecting a shipyard is the Commercial criterion (0.1353). Based on the weight of the criteria generated from the AHP, the highest ranking of the alternative shipyard choices is PT. ASL Shipyard (0.685).

Sensitivity analysis is done to determine how reliable the outcomes of the alternative selection are given the set of criteria. According to the selection findings, PT. ASL will still be selectable as the best

alternative shipyard even if the portfolio weight, supply chain network, and shipyard facilities are increased by 20%. The selection outcomes are the same as they would be if no adjustments were made to the AHP-derived criterion weights. However, PT. Citra Shipyard is the shipyard of choice with the condition that the commercial weight is increased by 20%, making commercial the predominant weight in the decision. However, in reality, shipyards hardly ever provide ship building costs with a reduction in price. Thus, it can be concluded that the results of the selection made produced a robust choice.

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