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Location Selection Analysis for New Shipyard Using Integration of DEMATEL and ANP: A Case Study (PT IKI)

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Abstract. A shipyard is a manufacturing industry that has a capital-intensive character with very high investment value to build the production facilities, requiring serious planning, handling, and management to survive and grow as a healthy industry. PT IKI headquartered in Makassar is planning to expand its business to one of three alternate areas (Ambon, Sorong, and Timika). Determining the location of the new shipyard from existing alternatives need to be done carefully using advance method due to the complexity of the factors and the interrelationship between factors, by first identifying factors that influence (dispatcher) and are influenced (receiver) in selecting shipyard locations and identifying their respective weights factors, will result in the selection of the most strategic location with comprehensive consideration. The influencing factors (dispatchers) and influenced (receivers) in the selection of shipyard locations were obtained by the DEMATEL method, the weight of each factor was analyzed using the DANP method with the results of raw material costs being a priority factor with scores value 13.73%, then the from AHP method obtained the most strategic alternative location is Ambon as the location of the new shipyard with a score value of 40.94%.

1. Introduction

One of the problems faced by the shipping industry today is the lack of production capacity to build new ship and repair maintenance facilities, this condition getting worse by the spread of shipyard industries in Indonesia that are not evenly distributed throughout the province (mostly in western Indonesia region) [1], causing commercial and pioneer passenger vessels operating in Eastern Indonesia have to send their ship outside of the region to maintain or repair, which inevitably results in increasing ship's non-productive time and increasing the maintenance costs due to additional fuel to mobilize the ship in to the shipyard location.

PT IKI headquartered in Makassar plans to develop shipyard facilities in new locations at eastern region (one of three alternate areas: Ambon, Sorong, and Timika) [2] to improve service to the national shipping industry. Currently, PT IKI has one branch in Bitung which only capable of ship repairs due to lack of facilities to build a new ship.

It is the first duty of investors to transform financial resources into investments in the right places at the right times and earn benefits. However, where to invest and how to invest is always a risky and complicated problem. The decision which will be made under a variety of factors might result in a terrible mistake if it is not felicitous. It is necessary to utilize scientific methods when deciding to make these types of complicated investments which can cause large financial losses [3]. Consideration of factors for selecting the location of the shipyard industry is the same as the selection of industrial sites in general, but in the shipbuilding industry, the location must have a coastline.

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In the shipbuilding industry, to choose priority locations that will be developed as a new location, influenced by many location criteria/factors that are interrelated between the factors, it is necessary to know what factors influencing other factors, and which factors are influenced in correlation to obtain factor score weight, so the research needs to be carried out using methods that are able to accommodate various factors that are interrelated and influence each other.

This research aims to find the best location for new shipyard in study case for PT IKI using decision making trial and evaluation laboratory (DEMATEL) to obtain receiver and dispatcher factor, integration of DEMATEL and Analytic Network Process (ANP) also known as DNAP to obtain scoring weight and rating for each factor, and finally using analytical hierarchy process AHP to determine preferable location based on defined factor with respect to score of each factor.

Some studies related to this method have been discussed as [3], [4], [5], [6] however the specific topic for shipbuilding industry has not been fully studied in practical, this study proposes a complex yet easy enough for shipyard's decision maker to map their perspective and preference to find a solution.

2. Literature Review

Shipyards can be interpreted as a place designed to accommodate the working process to build and repair a ship. Shipyards are usually built on extensive land because the final products are so large along with supporting facilities to conduct activities related to the new construction or repair of ships [7].

To deal with complex problems such as location selection factor which has intercorrelation between factors, structuring them through graphical representations and analyzing causal influences can aid in illuminating complex issues, systems, or concepts. The DEMATEL method is a methodology which can confirm interdependence among variables and aid in the development of a chart to reflect interrelationships between variables that can be used for researching and solving complicated and intertwined problem groups. The end product of the DEMATEL process is a visual representation "the impact-relations map" by which respondents organize their own actions in the world [8].

Analytic Network Process (ANP) is able to represent the importance of various parties by considering the interrelationships between the criteria and the existing sub-criteria [9]. The combination of DEMATEL and ANP is often used in determining alternative choices of complex problems, such as in investment selection [6], marketing strategies [10], and performance evaluation [11].

Integration of DEMATEL and ANP method consists of four steps [5]. The first step, based on the Network Relation Map and the total-influence matrix T, construct the network hierarchical structure of the observed system to the defined objectives. The second step is to calculate un-weighted Supermatrix W. The third step is to calculate the weighted Supermatrix W*w* as to normalize sums of influences of each group of factors in relation to all groups from the matrix of total group influences. The fourth step, a limited supermatrix is calculated by several multiplying of weighted supermatrix W*w* until the vector values in a limited supermatrix become stable.

3. Research Methodology

In this research, there are four steps to finally determine the best location for the new shipyard. **First**, define the factor and cluster (a group of factors) which in this research obtained from the previous study conducted by Guneri, et al (2009) dan Jaya (2017) including the recommendation to add more factor to add to the system, factor and cluster then consulted to experts to finalized the variables as shown in table 1.

The second step is to construct a questionnaire according to DEMATEL method with the aim to get perceptions from experts/respondents on the relationship between criteria, the final output of this method are graphical representations (Network Relation Map/NRM) and causal influences (dispatcher factor and receiver factor).

Respondents in this study were shipyard practitioners (board of directors from PT IKI), shipping consultant practitioners (board of directors from PT Sea Tech Indonesia), Academics (Lecturers in ship production, Department of Shipping Engineering, ITS Surabaya) who were directly or indirectly involved in the shipping industry, especially shipyards.

The **third** step is to calculate the weight of each factor using an integration of DEMATEL and ANP and get a rating score for each factor that influences the selection of the shipyard location. The **fourth** step is to construct another questionnaire in the pairwise comparison between each factor with respect to it's score to each location alternative and using the tools of Super Decision software we could calculate the final score for each location alternatives.

Table 1. cluster and factor that influence the selection of the shipyard location

No.	Cluster	Factor/Variable
1	Labor	A. Labor Quality
		B. Labor cost
		C. Labor supply
2	Environment	D. Geological
		E. Climate
		F. Transportation
		G. Structure demography
3	Region economy	H. Region economic situation
		I. Related industry situation
4	Raw material	J. Raw material cost
5	Physical conditions	K. Land cost
		L. Construction cost
		M. Enlargement of the shipyard
		N. Protection from sea condition
6	Technology	O. Reachability of technology
		P. Main facility
		Q. Investment relative cost
7	Government	R. Incentive/tax

4. Results and Discussion

The DEMATEL method is used to obtain the relationship between factors (presented in RC value) by accommodating the perceptions of the respondents who are experts in the shipyard industry (experts judgment), positive R-C value means the variable is influencing another variable (dispatcher) and negative R-C value means that the variable is influenced by other (receiver), based on the analysis result of data collection in table 2 shows that variable D (geological) and variable N (protection from sea condition) are the variables that most influence (the largest R-C values). Variable K (land cost), and variable L (construction cost) are the factors that most influenced by another variable with the smallest R-C value.

figure 1 is the NRM as a visual representation from DEMATEL method, drawn by using the R+C value as the horizontal axis and R-C as the vertical axis, then adding the line connecting the variables to represent their correlation. A line with one red arrow indicates a one-way influence relationship, while a line with two black arrows indicates two-way influence relationship between factor. There is a variable with no lines (E. Climate) means the variable does not influence or being influenced by another variable.

An integration of DEMATEL and ANP methods or commonly called the DANP method used to calculate the weight of each variable, where the output of the DEMATEL method in the form of total relationships between factors matrix (T matrix) is used as input to analysis by the ANP method, result in table 3 show that raw material cost has the highest score of 0.137 or 13.7% compared to the rest of the factor, and climate has the lowest score of 0.005 or 0.5% compared to all factor.

Table 2. correlation relationship status

Factor/variable	R+C	R-C	Status
A. Labor Quality	7.769	0.108	Dispatcher
B. Labor cost	11.045	-0.086	Receiver
C. Labor supply	10.712	-0.038	Receiver
D. Geological	3.947	3.947	Dispatcher
E. Climate	0.000	0.000	Neutral
F. Transportation	8.022	0.582	Dispatcher
G. Structure demography	4.585	-1.501	Receiver
H. Region economic situation	11.314	-0.192	Receiver
I. Related industry situation	11.610	-0.130	Receiver
J. Raw material cost	5.222	-0.950	Receiver
K. Land cost	3.754	-3.754	Receiver
L. Construction cost	7.511	-2.243	Receiver
M. Enlargement of the shipyard	10.586	0.091	Dispatcher
N. Protection from sea condition	3.921	3.921	Dispatcher
O. Reachability of technology	10.102	0.477	Dispatcher
P. Main facility	10.061	-0.363	Receiver
Q. Investment relative cost	10.535	0.120	Dispatcher
R. Incentive/tax	2.380	0.010	Dispatcher

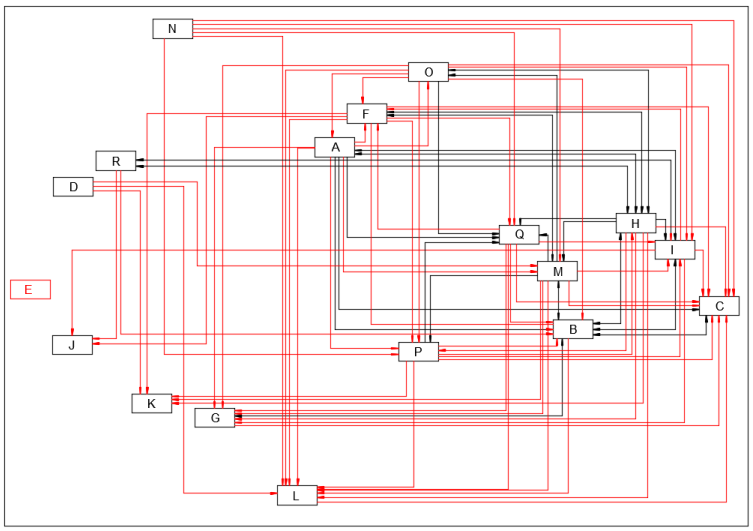


Figure 1. Network Relation Map

The final calculation to determine the alternative location for a new shipyard is the highest score of the supermatrix results between the weight of each factor according to the results of the DANP method in table 3 and the weight of each location alternative from the super decision software as in table 4.

Table 3. Results for each alternative from DANP method

No.	Cluster	Factor/variable	Weight	
1	Labor	A. Labor Quality	0.052	16.85%

		B. Labor cost	0.058	
		C. Labor supply	0.059	
2	Environment	D. Geological	0.010	8.97%
		E. Climate	0.005	
		F. Transportation	0.038	
		G. Structure demography	0.036	
3	Region economy	H. Region economic situation	0.087	17.58%
		I. Related industry situation	0.089	
4	Raw material	J. Raw material cost	0.137	13.73%
5	Physical conditions	K. Land cost	0.038	14.46%
		L. Construction cost	0.043	
		M. Enlargement of the shipyard	0.044	
		N. Protection from sea condition	0.020	
6	Technology	O. Reachability of technology	0.053	16.91%
		P. Main facility	0.058	
		Q. Investment relative cost	0.058	
7	Government	R. Incentive/tax	0.115	11.49%

Table 4. Results for each alternative from SuperDecision Software

Alternative	Factor/variable								
	A	B	C	D	E	F	G	H	I
A1. AMBON	0.742	0.661	0.443	0.493	0.333	0.683	0.726	0.400	0.333
A2. SORONG	0.183	0.208	0.387	0.311	0.333	0.200	0.172	0.400	0.333
A3. TIMIKA	0.075	0.131	0.169	0.196	0.333	0.117	0.102	0.200	0.333
Alternative	Factor								
	J	K	L	M	N	O	P	Q	R
A1. AMBON	0.594	0.097	0.547	0.135	0.493	0.540	0.122	0.157	0.122
A2. SORONG	0.249	0.333	0.263	0.584	0.311	0.297	0.558	0.594	0.558
A3. TIMIKA	0.157	0.570	0.190	0.281	0.196	0.163	0.320	0.249	0.320

Table 5. Final score results for each alternative

Alternative	Score	Ranking
A1. AMBON	0.4094	1
A2. SORONG	0.3642	2
A3. TIMIKA	0.2263	3

In this study, the DEMATEL method has successfully identified all variable as a dispatcher or receiver and take place on the same network presented with the NRM. Factors also to be evaluated numerically and prioritized among themselves, it has been seen as one of the best decision-making methods in the literature. However, this method is insufficient in explaining the ambiguity through the decision maker's decisions. In order to minimize this shortcoming, DANP method has been used instead of classical ANP.

"Davor's approach" [5] on DANP procedures has been adopted in this study, when considered that ANP and AHP work with the same logical architecture, which is favorable for network structure, it is obvious that approaches for AHP can also work for ANP [3], thus to eliminate repeated questioners for

DEMATEL and ANP that could cloud the judgment of the expert as respondent, AHP used for final stages to simplify the effort.

5. Conclusion and Further Studies

In this study integration of DEMATEL and ANP has been successfully conducted in the selection of a location for a new shipyard in this case for PT IKI is Ambon with score 0.409. It has been seen that it was important for the decision makers to understand fully the desired preference in forming mutual comparisons and in appointing the relation levels on the DEMATEL method. It has also been seen that selecting experts based on their experience, knowledge, and educational level are some of the most important issues in ensuring accuracy during the study and the results.

The requirement to build a new shipyard in order to meet the urgent need of shipping business in the eastern region of Indonesia was defined with this study. This decision has been made under today's circumstances so it is quite normal to have different results with the changing conditions in the future.

To get more accurate results and the precision of future research it is necessary to add the variable of raw material delivery time and the availability of raw material in the cluster (4) Raw material, and the addition of regional security factors. The number of the variable within the cluster influencing the weighting result of each variable, for further study needs to add additional variable other than incentives/taxes on the cluster (7) Government to ensure the balance of the final result. There is one variable that has no line in NRM (climate variable) which means the variable is not influencing nor influenced by other variable and could be eliminated for further study in Indonesia which has relatively same climate across the nation.

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