SELECTION OF LNG PLANT LOCATION USING MULTI ATTRIBUTE DECISION MAKING (*MADM*) METHOD

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ABSTRACT

This paper discusses the selection of LNG plant location. The availability of natural gas in Indonesia must be balanced with the development of LNG plant. Indonesia's gas reserves are located in Natuna (51.46 TCF), East Kalimantan (18.33 TCF), South Sumatra (17.90 TCF), Papua (24.32 TCF), West Java (3.70 TCF) and East Java (6.40 TCF). The most important thing to develop a refinery is determining the location of the LNG Plant development. Selection of LNG plant location use Multiple Attribute Decision Making (MADM). Multiple Attribute Decision Making (MADM) method is selection approach by defining the quantitative and qualitative attributes of the components. Attributes in LNG Plant location selection of include environment, construction, access, and cost. Each location has a preference score or similarity to ideal design on each attribute assessment. The most similarity to ideal design indicated the most suitable location. The selected location to develop small LNG Plant using Multi Attribute Decision Making (MADM) based on CODASID and AHP method is Location K. The Location K has score 1,00 for CODASID method, and score 0.299 for AHP method.

Keywords: **Attribute, LNG Plant, Multi Attribute Decision Making**.

INTRODUCTION

Liquefied Natural Gas (LNG) is a liquefied natural gas cooled to a temperature of -160 °C with atmospheric pressure, resulting a gas in liquid form. Prior to the cooling and condensation process of the natural gas, it is firstly distilled to remove impurities, such as carbon dioxide, sulfur air, and mercury (Michot, 2007).

Indonesia's gas reserves are located in Natuna (51.46 TCF), East Kalimantan (18.33 TCF), South Sumatra (17.90 TCF), Papua (24.32 TCF), West Java (3.70 TCF) and East Java (6.40 TCF) (Saleh, 2011). From the data of natural gas availability, Indonesia needs to build LNG Plant. Indonesia's gas reserves are relatively in small availability for each location, then the strategy for LNG plant development is by developing small LNG Plant. Small LNG plant, economically feasible to transport for distance of less than 400 nm and supply volume below 20 MMSCFD. Small LNG plant is very suitable to be applied in countries that have a complex geographical such as mountains, swamps, forests. (Hetland, 2004), (Mirza, 2008).

One of the common models experienced by humans is in taking an appropriate decision from various options (alternatives) with the many criteria (attributes / constraints / constants / limits). One of the most commonly used methods is Multiple Criteria Decision Making (MCDM). MCDM provides an alternative to take advantage of objective and subjective considerations as a basis for decision making. MCDM method is divided into two, namely: based on the selected attributes, known as Multiple Attribute Decision Making (MADM) and based on the synthesis of selected attributes, known as Multiple Objective Decision Making (MODM) (Kuntjoro, 2009).

MADM Approach (Multiple Attribute Decision Making) is a technique to select the multicriteria attributes, no classical mathematical approach is required. Decision variables are considered as finite discrete variables. This approach is only intended as a decision tool in order to learn and understand the problems faced, determine priorities, values, objectives through the exploration of the decision component making it easier for decision makers to identify which of the best options. Multiple Attribute Decision Making (MADM) uses a selection approach by first defining the quantitative attributes and qualitative attributes of the components to be selected. Where the criteria of considerations in performing an election can not be quantified entirely, so the selection process will tend to meet the MADM criteria.

METHODOLOGY

The computational procedures of MADM method by using *Concordance and Discordance Analysis by Similarity to Ideal Design* (CODASID) are as follows:

1. Model design problems to be solved on decision matrix, weight and possible veto threshold values for attributes.

Table 1. Decision matrix

Alternative design	Atrribute			
	y_1	y_2	….	y_3
a_1	y_{11}	y_{12}	….	y_{1n}
a_2	y_{21}	y_{22}	….	y_{2n}
…			….	
a_m	y_{m1}	y_{m2}	….	y_{mn}

Assessment of alternatives is performed with a score of 1 to 5 for quantitative data.
1 = very bad
2 = bad
3 = medium
4 = good
5 = very good

2. Create normalized decision matrix by means of equations 1 and 2, including the weighted normalized decision matrix and make non-outranking relationships.

$$r_{ij} = \frac{y_{ij} - y_j^{min}}{y_j^{max} - y_j^{min}}$$ Equation 1

$$y_j^{min} = min\{y_{1j} \quad y_{2j} \ \ldots \ y_{mj}\}$$ Equation 2

$$R = \begin{bmatrix} r_{12} & r_{12} & r_{1n} \\ r_{21} & r_{22} & r_{2n} \\ r_{m1} & r_{m2} & r_{mn} \end{bmatrix}$$ *normalised decision matrix*

$$Z = \begin{bmatrix} z_{12} & z_{12} & z_{1n} \\ z_{21} & z_{22} & z_{2n} \\ z_{m1} & z_{m2} & z_{mn} \end{bmatrix}$$ *Weighted normalized decision matrix*

$$N_a = \{(a_k, a_1) \mid y_j(a_1) - y_j(a_k) \geq vt_j \; for \; any \; j \in J \, ; k \, ; l \in M \, ; k \neq l\}$$

Non-outranking relationships

3. Each pair of alternatives **(a_k, a_1)** ***(k, l ε M; k ≠ 1)***, form a concordance set, and sum the preference corcondance index and evaluation concordance index. Formulate the preference corcodance index matrix and evaluation concordance index. Then, calculate the net preference concordance index **p_k** and net evaluation concordance index **e_k**, for ***k = 1, ..., m***

$$C_{kl} = \{j \mid y_{kl} \geq y_{lj} \, , j = 1, \ldots, n\}$$ *Concordance set*

$$D_{kl} = \{j \mid y_{kl} \leq y_{lj} \, , j = 1, \ldots, n\}$$ *Discordance set*

$$C_{kl} \cup D_{kl} = J = \{1 \quad 2 \ldots n\}$$

$$P_{kl} = \frac{\sum_{j \in C_{kl}} w_j}{S_p}$$ *Preference corcondance index*

$$e_{kl} = \frac{\sum_{j \in C_{kl}} |r_{kj} - r_{lj}|}{S_e}$$ *Evaluation concordance index*

$$PC = \begin{bmatrix} - & P_{12} & \ldots & P_{1m} \\ P_{21} & - & \ldots & P_{2m} \\ P_{31} & P_{32} & \ldots & P_{3m} \\ P_{m1} & P_{m2} & \ldots & - \end{bmatrix}$$ *Preference corcodance index* matrix (PC)

$$EC = \begin{bmatrix} - & e_{12} & \ldots & e_{1m} \\ e_{21} & - & \ldots & e_{2m} \\ e_{31} & e_{32} & \ldots & e_{3m} \\ e_{m1} & e_{m2} & \ldots & - \end{bmatrix}$$ *Evaluation concordance index* matrix

$$P_k = p(a_k) = \sum_{\substack{l=1 \\ l \neq k}}^{m} (p_{kl} - p_{lk}) \qquad k = 1, \ldots, m$$ *Net preference concordance index*

$$e_k = e\,(a_k) = \sum_{\substack{l=1 \\ l\neq k}}^{m} (e_{kl} - e_{lk}) \qquad k = 1, \dots, m$$ *Net evaluation concordance index*

4. For each alternative pair, form a discordance set and sum the discordance index. Formulate discordance index matrix DC and add net discordance index. Then find optimal settings using linear goal programming that is included in the veto threshold value count. In this step, the veto threshold is required to modify the inconsistency that occurs in the raw data.

$$d_{kl} = \left\{ \frac{1}{S_d} \sum_{j\in D_{kl}} |z_{kj} - z_{lj}| \right\} \quad if\ (a_k, a_1) \notin N_a$$ *Discordance index*

$$d_{kl} = \left\{ \frac{x_{kl}}{S_d} \sum_{j\in D_{kl}} |z_{kj} - z_{lj}| \right\} \quad if\ (a_k, a_1) \in N_a$$

$$DC = \begin{bmatrix} - & d_{12} & \dots & d_{1m} \\ d_{21} & - & \dots & d_{2m} \\ d_{31} & d_{32} & \dots & d_{3m} \\ d_{m1} & d_{m2} & \dots & - \end{bmatrix}$$ *Discordance index matrix*

$$d_k = d\,(a_k) = \sum_{\substack{l=1 \\ l\neq k}}^{m} (d_{kl} - d_{lk}) \qquad k = 1, \dots, m$$ *Net discordance index*

5. Summarize the information gap by the preference matrix and identify possible preference relationships with one alternative domin or domin derived from another preference space. Given t = 0 and initia trade off weight λ.

6. Create normalized preference matrix and weighted normalized preference matrix.

$$\bar{P}\bar{M} = \begin{bmatrix} \bar{p}(a_1) & \bar{e}(a_1) & \bar{d}(a_1) \\ \bar{p}(a_2) & \bar{e}(a_2) & \bar{d}(a_2) \\ \vdots & \vdots & \vdots \\ \bar{p}(a_m) & \bar{e}(a_m) & \bar{d}(a_m) \end{bmatrix}$$ *Normalized preference matrix*

$$\tilde{P}\tilde{M} = \begin{bmatrix} \tilde{p}(a_1) & \tilde{e}(a_1) & \tilde{d}(a_1) \\ \tilde{p}(a_2) & \tilde{e}(a_2) & \tilde{d}(a_2) \\ \vdots & \vdots & \vdots \\ \tilde{p}(a_m) & \tilde{e}(a_m) & \tilde{d}(a_m) \end{bmatrix}$$ *Weighted normalized preference matrix*

7. Define the ideal and nadir alternatives in the preference space if the best or least preferred design does not meet.

8. Calculate the distance on each alternative for the alternatives, and calculate the relative closeness index on each alternative for the alternatives.
9. Ranking all alternatives based on indicators of relative closeness (Yang, 1994).

RESULTS AND DISCUSSION

Data collection is taken by survey at 14 locations which planned to develop small LNG Plant, and agencies related to the data. The following data should be obtained in conducting research are as follows:

1. Wind speed
2. Waves
3. Depth of sea water / draught
4. Tidal
5. Availability of land
6. Length of pipeline
7. Jetty facilities
8. Future business development
9. Electricity network
10. Transportation facilities
11. Distance shore to highway
12. Cost for develop facilities
13. Cost for dredging
14. Cost for pipeline loading terminal

The data are grouped into four major attributes such as environment, construction, access, cost. Hierarchy of attributes location can be shown at figure 1.

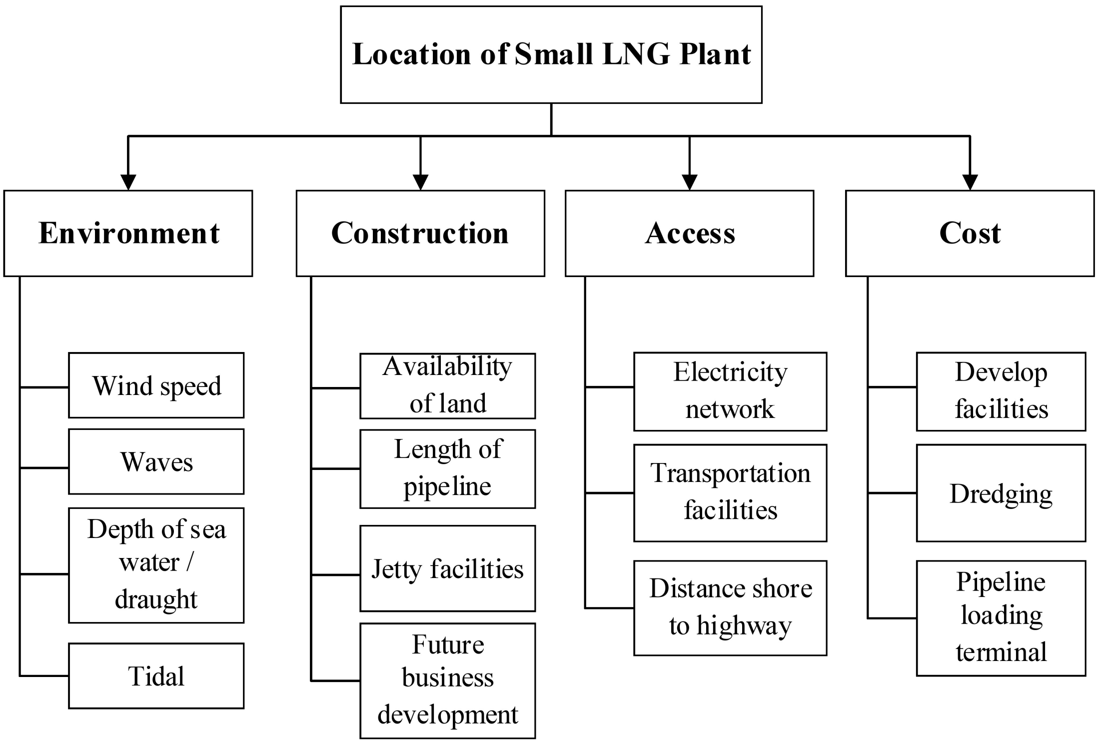

Figure 1. Attributes and Sub-attributes used in the selection of small LNG locations

Alternative locations of small LNG plant, namely location A-N and attributes are modeled by decision matrix, weight and possible veto threshold values for attributes. The decision matrix can be shown at Table 2.

Table 2. Decision matrix of Alternative Location and Attributes Small LNG Plant

Alternative Location	attribute (v_k)													
	Wind speed (knot)	wave (meter)	depth (meter)	tidal (meter)	Availability of Land	Length of pipeline (km)	Jetty facilities	future business dev.	electricity network	transportation	distance from highway (km)	cost of development	cost of dredging	cost of pipeline loading terminal
a_k	v_1	v_2	v_3	v_4	v_5	v_6	v_7	v_8	v_9	v_{10}	v_{11}	v_{12}	v_{13}	v_{14}
Location A	-20	-1	16	-1	4	-127	1	2	4	4	-2	1	2	1
Location B	-20	-1	16	-1	1	-123.7	1	2	4	4	-1.5	1	2	1
Location C	-20	-1	18	-1	1	-119.7	3	2	4	4	-1.5	2	2	2
Location D	-20	-1	20	-1	4	-106.8	1	3	4	3	-2	1	1	1
Location E	-20	-1	18	-1	1	-105.2	1	2	4	4	-2	1	3	1
Location F	-20	-1	12	-1	3	-105.1	1	2	4	4	-2	1	2	1
Location G	-20	-1	15	-1	2	-73.5	3	3	4	4	-3	2	1	2
Location H	-20	-1	11	-1	2	-69.4	1	2	4	4	-3	1	1	1
Location I	-20	-1	15	-1	3	-69.4	1	2	4	4	-3	1	1	1
Location J	-20	-1	14	-1	1	-70.3	1	2	4	4	-3	1	1	1
Location K	-20	-1	21	-1	5	-70.5	4	4	4	4	-3	3	3	3
Location L	-22	-1.2	20	-1.8	3	-98	1	2	4	4	-3	1	2	1
Location M	-22	-1.2	20	-1.8	3	-110.8	1	2	4	4	-1.5	1	2	1
Location N	-22	-1.2	20	-1.8	5	-111.6	4	4	4	4	-1	3	3	3

Furthermore, following the steps of CODASID method can be determined the most suitable location to develop a small LNG Plant. Selection result of small LNG location using CODASID method, the location with the highest preference is **Location K** with score of 1. The five highest score under **Location K** are **Location N** (0.709), **Location G** (0.468), **Location C** (0,4003), **Location D** (0.354) and **Location A** (0.251). While the location with the lowest score is **Location L** with a score 0, followed by **Location M** (0,034), **Location J** (0,154), **Location H** (0,1603), **Location B** (0,165). The magnitude of the similarity with the ideal design indicates that the location is a suitable location to be selected. So by using CODASID method, the suitable location is **Location K**. Summary of the results of selected location can be shown in Table 3.

Table 3. The Result of Selected Location Using CODASID Method

Alternative	s^{*1}	s^{-1}	$u(a_1)$
Location K	0	0.628504676	1
Location N	0.182727657	0.44673787	0.709709826
Location G	0.334250809	0.294850891	0.468685574

Alternative	s^{*1}	s^{-1}	$u(a_1)$
Location C	0.38019581	0.253829568	0.40034607
Location D	0.407716684	0.224366012	0.354963067
Location A	0.472569669	0.158915457	0.251653524
Location E	0.475921296	0.157276181	0.248384093
Location I	0.476955951	0.152851983	0.242696185
Location F	0.482088455	0.148046389	0.234943982
Location B	0.535248318	0.106156413	0.165506127
Location H	0.529844933	0.10122269	0.160399117
Location J	0.53945857	0.098572051	0.154494232
Location M	0.607129507	0.021701175	0.034510363
Location L	0.628504676	0	0

The calculation results in Table 2 can be proved or validated using *Analytical Hierarchy Process* (AHP) method. The AHP method is used as a comparator to the CODASID calculation whether the count indicates the appropriate result. The AHP method used a level of importance approach in assessing an alternative. By using AHP method and the same attributes, result of selsected small LNG Plant location is Location K score 0,299. Locations under Location K are Location N (0,263), Location G (0,132), Location C (0,107), Location A (0,104) and Location D (0,096). From the approach of the selected location by AHP method is Location K. Summary of the results of selected location by AHP method can be shown in Figure 2.

Figure 2. The Result of Selected Location Using AHP Method

Based on the comparison of CODASID and AHP method, the highest score is Location K. The ranking comparison between the CODASID and AHP methods can be shown in Table 4.

Table 4. The Comparison Result of Selected Location Using CODASID and AHP Method

Alternative	CODASID Method		AHP Method	
	Result	Rank	Result	Rank
Location K	1	1	0.299	1
Location N	0.709	2	0.263	2
Location G	0.468	3	0.132	3
Location C	0.400	4	0.107	4
Location D	0.3549	5	0.096	6
Location A	0.251	6	0.104	5

The condition of **Location K** as a suitable location to develop small LNG plant due to:

1. Availability of transportation facilities from shore to highway
2. Availability of communication network
3. Availability of phone signal and TV network
4. Availability of electricity network
5. Availability of port facilities
6. Adequate land to build LNG plant

Description of Location K as selected location to develop small LNG Plant is shown in Figure 3.

(a) Jetty Facilities (b) Adequate land

Figure 3. Description of Location K as Selected Location to Develop Small LNG Plant

CONCLUSION

Based on the explanation above, can be concluded as follows:

1. The selected location to develop small LNG Plant using Multi Attribute Decision Making (MADM) based on CODASID and AHP method is **Location K.** The Location K has score 1,00 for CODASID method, and score 0.299 for AHP method.
2. The condition of **Location K** as a suitable location to develop small LNG plant due to:
   - Availability of transportation facilities from shore to highway
   - Availability of communication network
   - Availability of phone signal and TV network
   - Availability of electricity network
   - Availability of port facilities
   - Adequate land to build LNG plant

ACKNOWLEDGEMENTS

The authors would like to be obliged to the agencies for accompanying and providing technical data during observation process.

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