GROSTLOG 2018
Global Research on Sustainable Transport & Logistics

ISSN: 2622-5778 (online)
Advances in Transportation and Logistics Research
http://proceedings.itltrisakti.ac.id/index.php/atlr

A Decision-Making Model for Locating The Place of Refuge for Distressed Ship: A Case of East Malaysia

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Abstract

Maritime transportation has become an important industry in enabling a global economy. This industry faces a tremendous development in the previous year's ranging from an integrated management to an advanced technological system. With the increasing number of vessels which indirectly result in many accidents, the role of Place of Refuge (PoR) is nowadays reappearing to be important as a place of shelter whereby the vessel in need of assistance can recover from damages or loss of property at sea. In East Malaysia, up to now there is no single PoR for distressed vessel which raised a concern among shipping operators. Concerning this critical issue, this paper proposes a PoR should be developed in Malaysia by focusing on Sabah & Sarawak states (East Malaysia). As a result, the primary of this paper is to develop a mathematical decision-making model for locating the PoR in East Malaysia. Firstly, the necessity of PoR in East Malaysia will be investigated. Secondly, the critical factors for locating the PoR in East Malaysia will be identified. Finally, three potential location will be assessed prior to selecting the best location among them. In order to achieve this aim, two mathematical methods will be employed which are Analytical Hierarchy Process (AHP) and Evidential Reasoning (ER). It is expected that this study is capable of assisting maritime government agencies such as Ministry of Transporation (MOT), Marine Deparment and other related agencies on developing the PoR in Malaysia.

Keywords: Decision-making model, Place of Refuge (PoR), maritime transportation, Analytical Hierarchichal Process (AHP), Evidential Reasoning (ER)

Introduction

Maritime transport playing a crucial role in global trade, were 90% of world trade in goods are dominated by vessels (International Chamber of Shipping (ICS), 2017). Therefore, the implementation of safety management is important in the maritime industry because safety is an important factor that affects maritime transportation (Galić *et.al*., 2014). Malaysia trade is carried by vessels is 98.4% (Maritime Institute of Malaysia (MIMA), 2017).

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Despite of advance technology, there is always a risk for sea accidents occurs that involving vessels. With the increasing number of vessel which indirectly result in many accidents, the role of Place of Refuge (PoR) is nowadays reappearing to be important as a place of shelter whereby the vessel in need of assistance can recover from damages or loss of property at sea.

What a measurement that have to be taken when suddenly a vessel in distress need an assistance request for a shelter place? Therefore, number of codes, conventions and guidelines regarding safety of shipping been introduced. International Maritime Organization (2004) Guidelines on Places of Refuge for Ships in Need of Assistance, Resolution A.949(23) are guidelines that assist coastal states to help the vessel in distress that need a place for shelter. In this research, it is necessary to develop a PoR in Malaysia where will be focus in East Malaysia. According to Galić et.al. (2014), sea accidents is an unexpected event that can occur under any circumstances that only thing can do is to assist and assess it. There are few sea accidents happened in East Malaysia. On 27 July 2012, a fire on board that caused explosive of MT Bunga Alpinia, at 2.30 am, Labuan (Borneo Post Online, 2012). MT Bunga Alpinia is a chemical tanker vessel own by Malaysia International Shipping Corporation with 29 crew on board. This accident has cause one crew on board dead. In East Malaysia, up to now there is no single PoR for distressed ship which raised a concern among shipping operators. Regarding this issue, this paper proposes a PoR should be developed in Malaysia by focusing on Sabah & Sarawak states (East Malaysia). Firstly, the necessity of PoR in East Malaysia will be investigated. Secondly, the critical factors for locating the PoR in East Malaysia will be identified. Finally, three potential location will be assessed prior to selecting the best location among them.

Usually, granted a PoR for vessel in need of assistance was necessary in order to save human live on board from vessel in distress (Noyes, 2008). The necessity to of PoR developed in East Malaysia is to help vessel in distress especially vessel that registered under Malaysia flag. As discussed earlier, there are few maritime accidents does happen at East Malaysia water areas and Figure 1

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show the total numbers of vessel come to berth at East Malaysia shows the maritime industries at East Malaysia is quite busy too. It is proved why PoR has to be developed in East Malaysia.

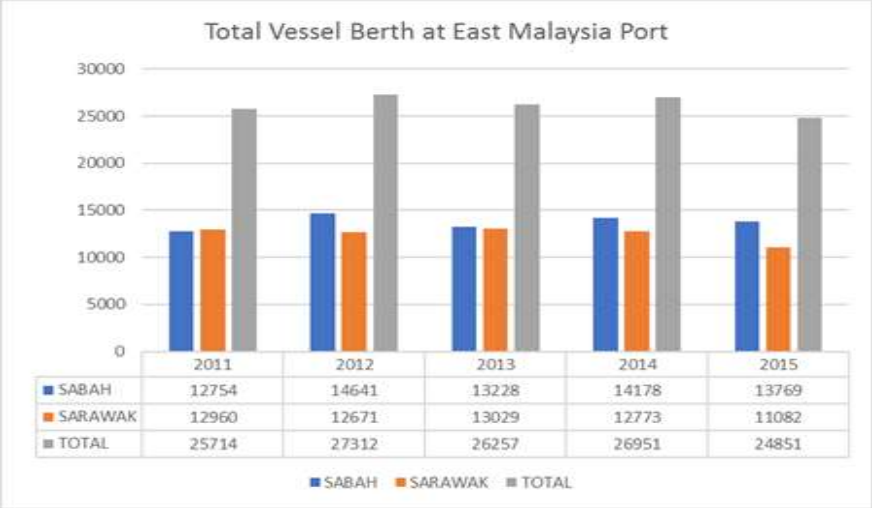

Figure 1. Total Ships Berth at East Malaysia Port from 2011-2015. Source: Malaysia Marine Department.

It is important to protect ecological and economic resources, and marine environment from any threat by providing PoR for vessel in distress (National Plan Strategic Coordination Committee, 2015). IMO (2004) explained the longer vessel in distress remained in the open sea, the risk to give more damage such oil pollution to the environmental. Malaysia have marine and coastal areas rich in biodiversity especially East Malaysia. For example, Malaysia shoreline rich with mangroves which 61% from Sabah and 21% from Sarawak (Ministry of Natural Resources and Environment (NRE), 2016). This socioeconomic and environmental is important at East Malaysia and must be protected from pollution. By designated a PoR for vessel in distress in Sabah and Sarawak water areas, the impact of the pollution can be minimized. PoR is necessity for vessels crew, passengers and salvage crew safety (National Plan Strategic Coordination Committee, 2015). When vessel having difficulty or in need of assistance, the safety of life of persons risk must be considered (IMO, 2004). IMO (2004) emphasized on of the main

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purpose of PoR is to reduce the hazard navigation. It is important to ensure the vessel accident such as collision will not disturb the safety of navigation and marine traffic (Van Hooydonk, 2004). By providing PoR to distress vessel, it will keep the other vessel within water areas safe from any dangerous.

There are several researched have been conducted in a particular of "Place of Refuge" (PoR) issues such as practical aspects, legal problems and a place of shelter (Li, 2005; Wenchi, 2006; Ucar, 2006; Ohlson, 2006; Morrison, 2011; Ready, 2014). Table 1 show the summary review from previous research. Based on previous researches, none of them however develop a decision-making model for locating the PoR based on a mathematical model, which this current research is important.

Table 1. Summary Review from Previous Research of POR.

Author	Focus
Li, (2005)	Investigate right of vessel in distress enter PoR.
Yang, (2006)	Investigate and clarify existing international conventions and customer law related to PoR.
Ucar, (2006)	Inspects PoR issue as a measure to protect marine environment.
Ohlson, (2011)	Study of national measures to afford for such PoR following standard from IMO guidelines and European Union legislation.
Morrison, (2011)	Analyse proposal voluntary Guidelines by IMO and Comite Maritime International (CMI) for separate convenation on PoR and assess adequacy to deal with future incidents.
Ready, (2014)	Discover potential locations around the island for possible future designation for PoR.

Compiled by Authors

In order to select the best place for "Place of Refuge" (PoR) in East Malaysia, firstly, the decision factors need to be identified which is environmental factors, socio-economic factors, navigational assistance, technical resources and accessibilities, and supporting establishment.

ISSN: 2622-5778 (online)
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IMO Guidelines on PoR recognized that environmental is a vital factor that consider to developed PoR (IMO, 2004). For centuries, the obligation to offer refuge is importance, but has recently started to be emphasized in the rise of environmental concerns due response to vessel incidents like Torrey Canyon (Storgårds, 2012). Coastal States concern towards environment is the main reason to deny refuge from distress vessel (Storgårds, 2012). Therefore, environmental factors are important as one of PoR developing criteria. Many coastal states refuse to grant PoR to distress vessel is because the nations concern potential socioeconomic damage to their coastlines (Ready, 2014). Several high-profile vessel incidents that give negative impact to socioeconomic because of oil pollution after been deny entering PoR could be minimize if the request of PoR been accept (IMO, 2004). Donner (2008) stated that if a vessel requests a PoR, the vessel lost the ability to manoeuvre is because the damage it has faced is serious. He also added due to the lost ability to manoeuvring the vessel, the risk to collide with PoR structure is higher than collision with another vessel. Therefore, navigational aid is importance to assist those vessels in distress when access to PoR. Efficiency PoR performance depends on the facilities and resources to discharge the damage vessel's cargo and repair structural damage (John, 2011). Accessibility is interaction, which are access or connect between one place to another place (Bruinsma and Rietveld, 1998). That is why technical resources and accessibility is important factor too. Supporting establishment is important to assist vessel in distress before entering to PoR. Supporting establishment is an agency or firm that establish to do their significant own roles. In Malaysia, there are several agencies that have important roles in maritime industries such as Malaysian Maritime Enforcement Agency (MMEA), Fire and Rescue Department of Malaysia.

In this research, two methods of multi-criteria decision making (MCDM) which are the Analytic Hierarchy Process (AHP) and Evidential Reasoning (ER). With AHP,decision-makers produce pair-wise comparison, based from the experts judgements in order to prioritize each criteria (Castilo et al., 2017; Gupta et al.,

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2017). In the AHP method, the use of new values is not enough to deal with the uncertainty because of the unclear of human subjective judgements (Ng, 2016). Therefore, ER was applied to support AHP because of the ability to handle uncertain or incomplete information (Ng, 2016). Xu and Yang (2001) explained The ER approach uses a extended decision matrix, which is each attribute of an alternative is described by a distributed assessment using a belief structure.

Methodology

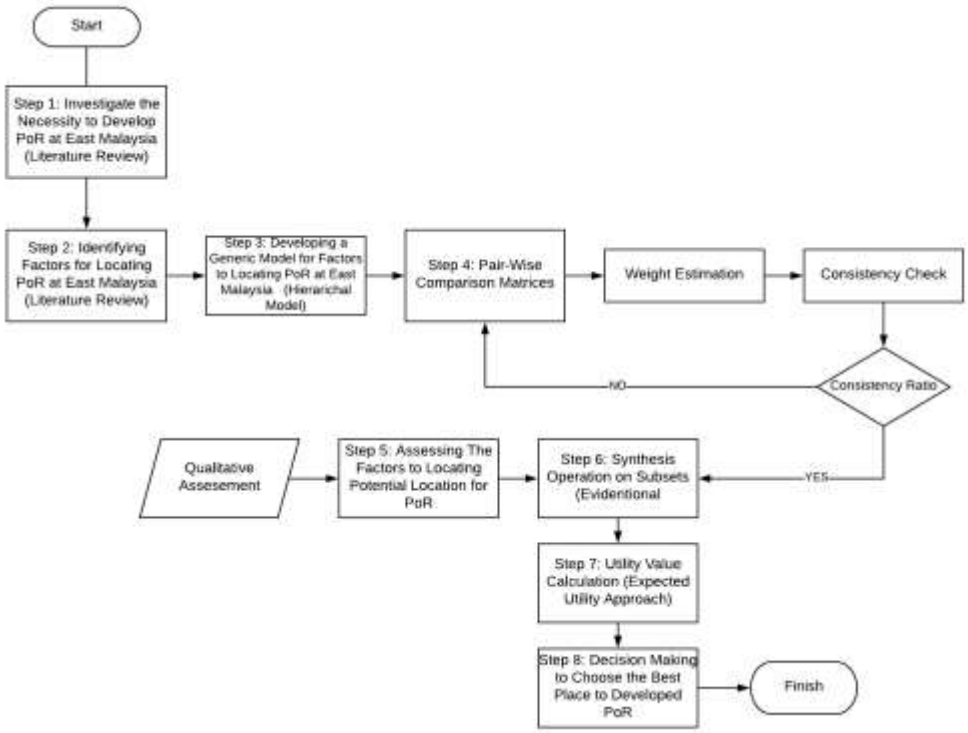

Figure 2. A Decision-Making Model Flow Chart.

Figure 2 shown eight steps needed to develop the decision-making model to locating PoR in East Malaysia by using AHP and ER method.

Step 1: Investigate the Necessity.

In this study, the necessity to ddevelop PoR at East Malaysia have been identified through literature review.

Step 2: Identifying Factors.

Factors for locating PoR at East Malaysia has been identify through literature

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review process.

Step 3: Developing Generic Model.

Developing a Generic Model for Factors to Locating PoR at East Malaysia.

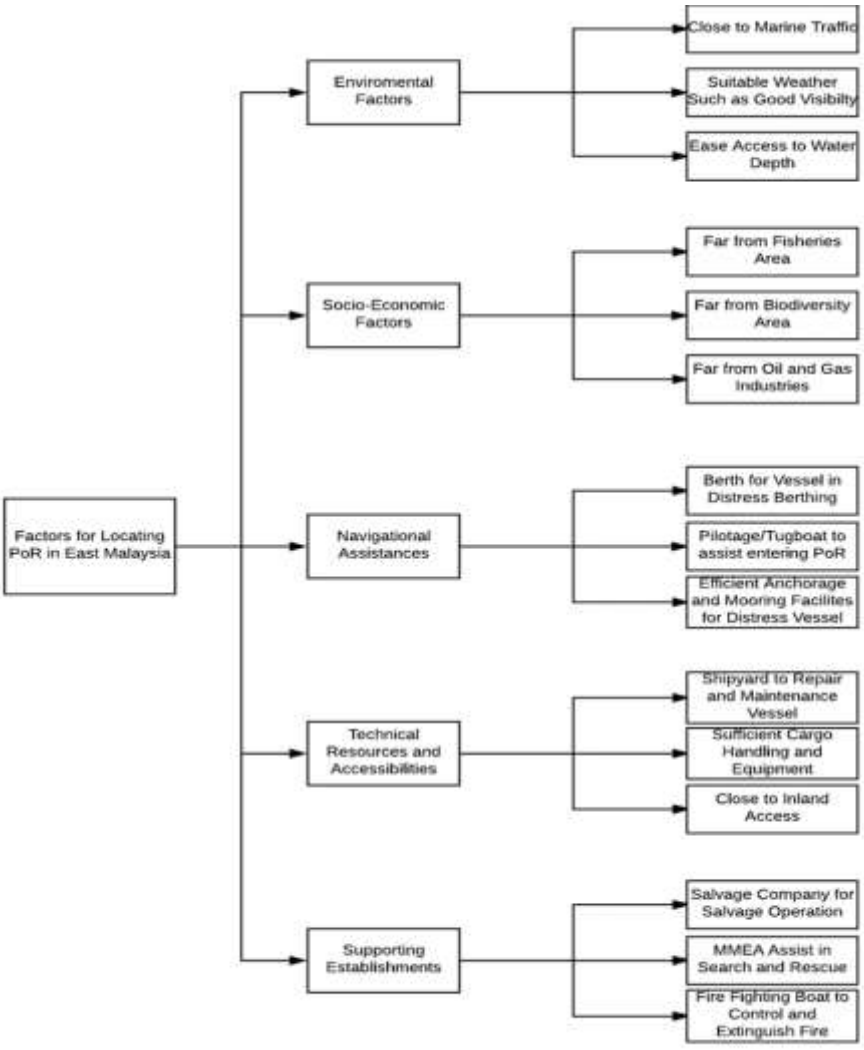

Figure 3. Factors Model to Locating PoR at East Malaysia.

Figure 3 shows five main factors to locating PoR at East Malaysia which is environmental factors, socioeconomic factors, navigational assistance, technical resources and accessibilities, and supporting establishment. Each main factor has been separated into three sub-criteria.

Step 4: Pair-Wise Comparison.

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Pair-Wise Comparison where AHP method will be using to measures the weight criteria through pair-wise comparison. Table 2 below show the range of scale for pair-wise comparison that will test the importance of the five main factors. This scale of range has been developed by Saaty (1986).

Table 2. Scale of Importance.

Intensity of Importance	Definition
1	Equal importance
3	Moderate importance of one over another
5	Essential or strong importance
7	Demonstrated importance
9	Absolute importance
2, 4, 6, 8	Intermediate values between the two adjacent judgments

Source: Saaty, 1986.

As shown in formula, $\boldsymbol{A_i}$ is the factor on left side, then $\boldsymbol{A_j}$ is the factor on the right side. The judgment of pair-wise comparison of $\boldsymbol{A_i}$ and $\boldsymbol{A_j}$ are presented by an $n \times n$ matrix D. This $\boldsymbol{a_{ij}}$ judgement will be done by doing the following rule:

- Rule 1: If $\boldsymbol{a_{ij}} = \alpha$, then $\boldsymbol{a_{ji}} = 1/\alpha$, $\alpha \neq 0$.
- Rule 2: If $\boldsymbol{A_i}$ is judged to be of equal relative importance as $\boldsymbol{A_j}$, then $\boldsymbol{a_{ij}} = \boldsymbol{a_{ji}} = 1$

With two rules given above, the matrix D is shown as follows:

$$D = \begin{pmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \dots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{pmatrix} \quad (1)$$

In this formula, i, j = 1,2,3…, n and each $\boldsymbol{a_{ij}}$ will be relative rank of alternative $\boldsymbol{A_i}$ to alternative $\boldsymbol{A_j}$. As shown in the matrix D, $\boldsymbol{a_{ij}}$ is a quantified judgement of assessment between $\boldsymbol{A_i}$ and $\boldsymbol{A_j}$. The next stage is using the formula to evaluation the weightage for each factor, where it will show which one of factors more

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outstanding among others (Riahi *et al.*, 2012; Salleh *et al.*,). Weight value symbol, $w_k$can be determine with the formula as below:

$$w_k = \frac{1}{n}\sum_{j=1}^{n}\left(\frac{a_{kj}}{\sum_{i=1}^{n} a_{ij}}\right)(k = 1,2,3,\dots n) \quad (2)$$

There are three formulas of Consistency Ratio (CR) that used to measure inconsistency of the pair-wise comparison. The consistency of the pair-wise considered reasonable if CR value is 0.10 or less, then the AHP method can proceed to computation weight vectors (Anderson et al., 2008; Riahi et al., 2012; Salleh et al., 2015). The three formulas to test CR shown as follow (Andersen et al., 2008):

$$CR = \frac{CI}{RI} \quad (3)$$

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (4)$$

$$\lambda_{max} = \frac{\sum_{j=1}^{n}\left(\frac{\sum_{k=1}^{n} w_k a_{jk}}{w_j}\right)}{n} \quad (5)$$

Where CI is the consistency index, then RI is the average random index as shown in Table 3, *n* is the number of factors being compared, and λ_{max} is the maximum weight value of the *n* x *n* matrix *D.*

Table 3 Random Index *n* is the Number of Factors.

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Step 5: Assessing the Factors to Locating Potential Location for PoR.

Judgements from expert field is one of the qualitative methods to collect data. linguistic variables are the way to representing the qualitative factors (Riahi et al., 2014).

Step 6: Synthesis Operation on Subsets (Evidential Reasoning).

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The assessed from upper level through lower level attribute association, ER Algorithm helps to aggregate multi-attributes in a hierarchical structure (Salleh et al., 2014). The synthesis will be conduct as formula below:

$$\tilde{E} = \tilde{E}_1 \oplus \tilde{E}_2 \quad (6)$$

To display this formula, $\tilde{E}$ will indicate the whole set of expressions and it will be assessed by aggregating two subsets, $\tilde{E}_1$and $\tilde{E}_2$as follows:

$$\tilde{E} = \{(\beta^1, very\ low), (\beta^2, low), (\beta^3, medium), (\beta^4, high), (\beta^5, very\ high)\}$$

$$\tilde{E}_1 = \{(\beta_1^1, very\ low), (\beta_1^2 low), (\beta_1^3, medium), (\beta_1^4, high), (\beta_1^5, very\ high)\}$$

$$\tilde{E}_2 = \{(\beta_2^1, very\ low), (\beta_2^2, low), (\beta_2^3, medium), (\beta_2^4, high), (\beta_2^5, very\ high)\}$$

In this paper, the terminologies in subset are “not suitable”, “low suitable”, “fairly suitable”, “very suitable”, and “absolutely suitable”. These terminologies of subset will associate with their matching degrees of belief. When m= 1, 2, 3, 4, 5, M_1^m and M_2^m are the individual degree to where the subsets $\tilde{E}_1$ and $\tilde{E}_2$ support the hypothesis that the assessment is confirmed to the five expressions.

Step 7: Utility Value Calculation.

From result of factor assessment, three linguistic terms will represent which is high, medium, and low. Next, a single value that obtain through utility value will used for decision makers and rank the alternatives available and further make comparison between alternatives.

$$u\left(H_n = \frac{V_n - V_{min}}{V_{max} - V_{min}}\right) \quad (7)$$

$$U_v = \sum_n^N \beta_n^U (H_n) \quad (8)$$

Discussion and Result

There are total of five experts has been interviewed. The following five experts are two marine officers from Bintulu Port Authority, a senior pilotage manager from Bintulu Port Sdn Bhd, a marine officer form Malaysia Marine Department, and an operation officer from Malaysian Maritime Enforcement

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Agency. Questionnaires were provided to assist the experts during interview sessions.

In this research, AHP has been used to test the validity of collected data. The validity of collected data is in CR which is the values of CR must be less or equal to 0.10. In this study, there are five main factors which is environmental factors, socioeconomic factors, navigational assistance, technical resources and accessibility, and supporting establishment that calculating in weight value. Table 4 shown the consistency ratio for a decision-making model for locating the PoR for distressed vessel in East Malaysia. The CR of the main factors is 0.0051 and the data collected is valid. For sub-factors, the highest consistency ratio is socio economics factors (0.0357), followed by navigational assistance (0.0010), supporting establishment (0.0006), environmental factors (0.0001), and technical resources and accessibility (0.0001).

Table 4. The Consistency Ratio for A Decision-Making Model for Locating the PoR for Distressed Vessel: A Case of East Malaysia.

Main Factors	Consistency Ratio for Main Factors CR ≤ 0.1	Sub-Factors	Consistency Ratio for Sub-Factors CR ≤ 0.1
Environmental Factors	0.0051	Close to marine traffic	0.0001
		Suitable weather such as good visibility	
		Ease Access to Water Depth	
Socioeconomic Factors		Far from fisheries area	0.0357
		Far from biodiversity area	
		Far from oil and gas industries	
Navigational Assistance		Berth for vessel in distress berth	0.0010
		Tugboat/Pilotage to assist entering PoR	
		Efficient anchorage and mooring facilities	
Technical Resources and Accessibility		Shipyard to repair and maintenance vessel	0.0001

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		Sufficient cargo handling equipment	
		Close to inland access	
Supporting Establishment		Salvage company for salvage operation	0.0006
		MMEA assist in search and rescue	
		Fire fighting boat to control and extinguish fire	

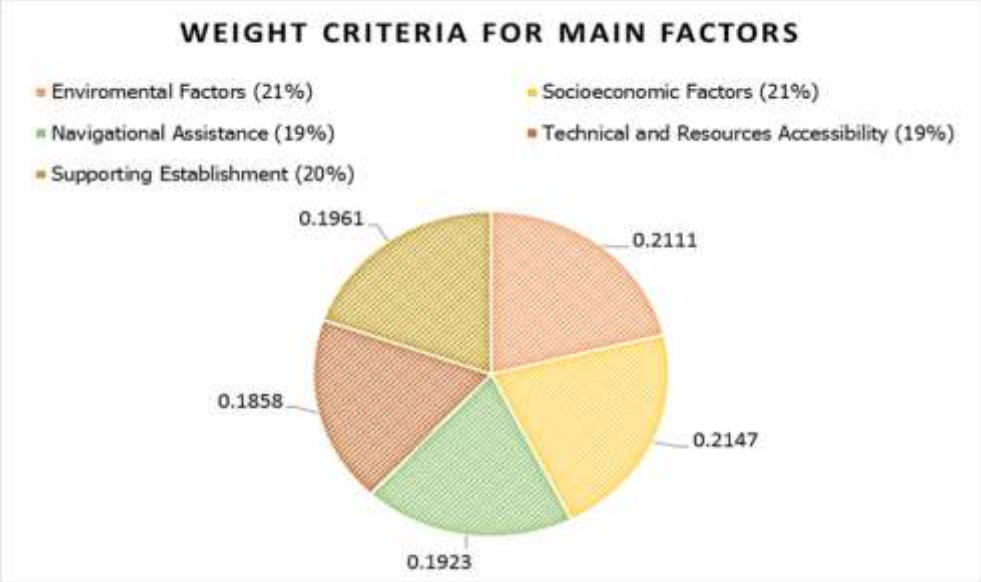

FIGURE 4. AHP Weight for Main Criteria

Figure 4 presents the weight value for the main factors for locating PoR in East Malaysia by using AHP method. The highest weight is socioeconomic factors with 0.2147 (21%). Second is environmental factors with 0.2111 (21%). Third is supporting establishment with 0.1961 (19%). Fourth is navigational assistance with 0.1923 (19%). The last place is technical resources and accessibility with 0.1858 (19%).

Table 5 showed the belief degree and utility value for sub-criteria of Kota Kinabalu. Utility value is value that obtained through aggregating belief degree by using IDS software. While belief degree is the outcome of aggregation from

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qualitative assessment. In Kota Kinabalu, the most significant sub-criteria is suitable weather, ease access to water depth, berth for vessel in distress berthing, pilotage assist to entering PoR MMEA assit in search and rescue and close to inland access (100%). By using the same method apply to Miri and Bintulu too. Figure 5 shows the utility value of main criteria for Bintulu, Miri and Kota Kinabalu. Among them, Bintulu has the highest utility value for environmental factors (0.9177) and navigational assistance (0.9703). Meanwhile, Kota Kinabalu scores the highest utility value of socioeconomics factors (0.5027), technical resources and accessibility (0.8429) and supporting establishment (0.8045). As a result, through the assessment of all factors, the alternatives that have the highest average score is Kota Kinabalu with 0.7921. Which mean Kota Kinabalu is the best location in East Malaysia to develop PoR. Overall result of decision-making model for locating PoR in East Malaysia can be seen on Figure 6.

Table 5. Evaluation outcome for sub-criteria (Kota Kinabalu)

Sub-Criteria	Not Suitable	Low Suitable	Fairly Suitable	Very Suitable	Absolutely Suitable	Utility Value
Close to Marine Traffic	0	0	0.9476	0.0524	0	0.5131
Suitable Weather such as Visibility	0	0	0	0	1	1
Ease Access to Water Depth	0	0	0	0	1	1
Far from Fisheries Area	0. 1878	0. 4225	0. 1371	0. 1775	0. 0751	0.3824
Far from Biodiversity Area	0	0	1	0	0	0.5000
Far from Oil and Gas Industries	0	0.1720	0.1720	0.6560	0	0.6210
Berth for Vessel in Distress Berthing	0	0	0	0	1	1
Pilotage/Tugboat to assist entering PoR	0	0	0	0	1	1
Efficient Anchorage and Mooring Facilities for Distress Vessel	0	0	0.8522	0.1478	0	0.5369
Shipyard to Repair and Maintenance Vessel.	0	0	0.1720	0.1720	0.6560	0.8710
Sufficient Cargo Handling and Equipment	0	0	0	0.5000	0.5000	0.6250
Close to Inland Access	0	0	0	0	1	1
Salvage Company for Salvage Operation	0	0. 9028	0. 0139	0. 0416	0.0417	0.3056
MMEA Assist in Search and Rescue	0	0	0	0	1	1
Fire Fighting Boat to Control and Extinguish Fire	0		0	0	1	1
Goal Result	**0.0106**	**0.07594**	**0.2268**	**0.0975**	**0.5875**	**0.7921**

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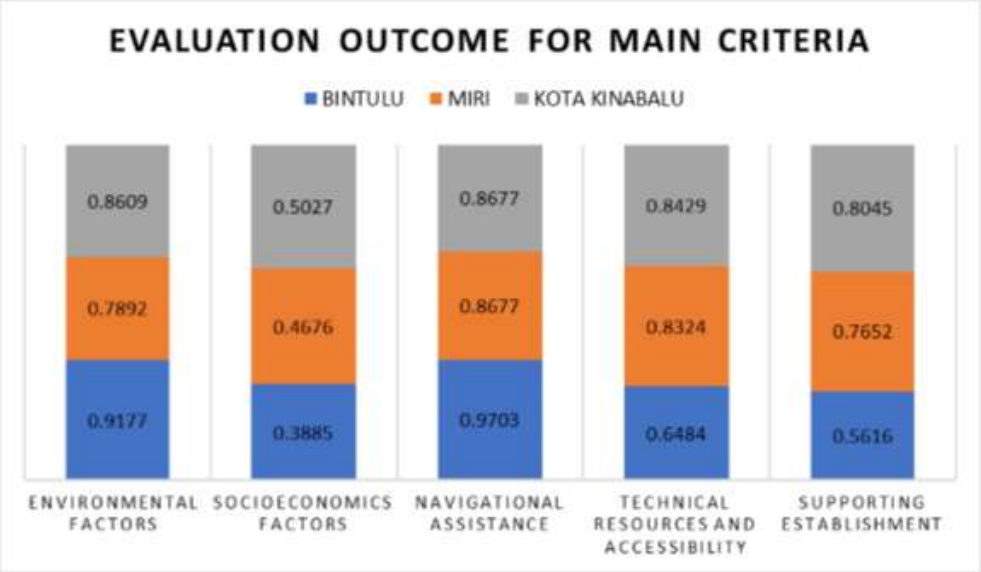

Figure 5. Utility Value for Main Criteria

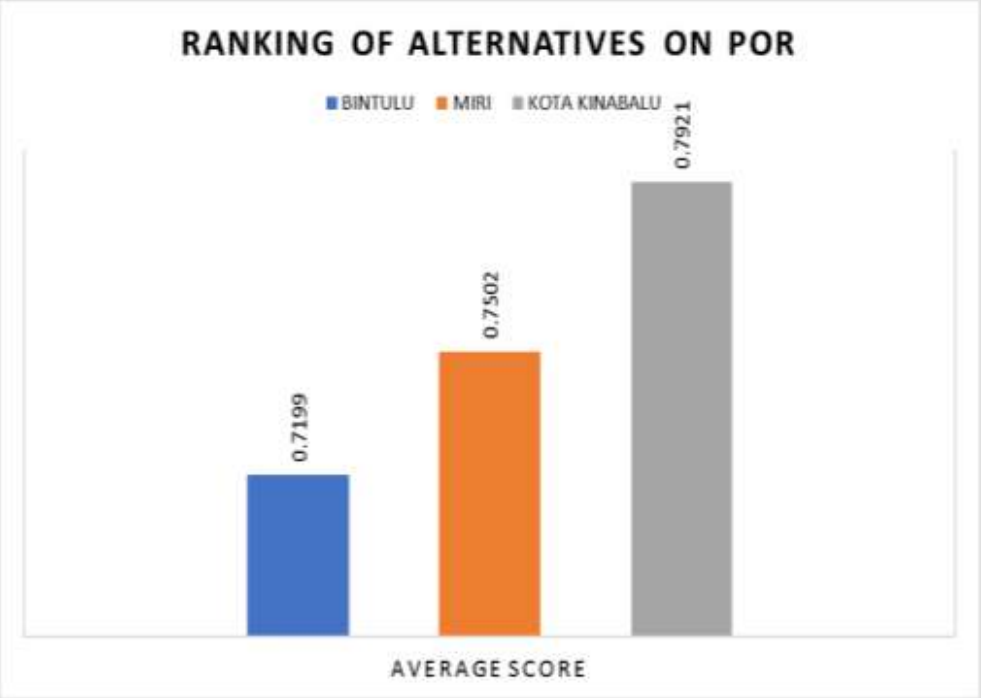

Figure 6. Average Score of Alternatives of PoR

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Conclusion

In East Malaysia, there is no single PoR was develop yet. PoR is important to save vessel in distressed where PoR can be a placed for shelter and recover from damaged or property loss. In this research, a decision making to choose the best place to develop PoR at East Malaysia by using a mathematical model as a decision-making method. Five main factors have been identified and investigated which is environmental factors, socioeconomic factors, navigational assistance, technical resources and accessibility, and supporting establishment. As a result, it is found that socioeconomics factors are the vital factor to locating PoR in East Malaysia. Three potential location which is Kota Kinabalu, Miri and Bintulu have been assessed to chooses the best alternative to develop PoR among them. Through the assessment of all factors, the alternatives that have the highest average score is Kota Kinabalu with 0.7921. Thus, Kota Kinabalu is the most suitable place to develop PoR in East Malaysia. It is expected that this study is capable of assisting maritime government agencies such as Ministry of Transporation (MOT), Marine Deparment and other related agencies on developing the PoR in Malaysia

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