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Evaluating Suitable Marine Transportation Vessel Options for the Efficient Distribution of Relief Materials to the Damare IDP Camp in Northeast Nigeria

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Abstract Marine routes may offer a safer means of transportation, reducing the risks associated with land-based convoys. Marine vessels can navigate through rivers and lakes, offering a faster and more efficient means of transporting relief materials compared to overland routes that may be congested or unsafe. The evaluation process involves the consideration of several subjective factors. The decision-making process is often intricate and occasionally marked by conflicting criteria, which presents a notable challenge. In contrast to the traditional method of selecting marine vessels for various tasks, the AHP-EDAS approach offers a more systematic means of identifying and evaluating the most suitable marine transportation vessel options for the efficient distribution of relief materials to the Damare IDP camp in northeast Nigeria. Within this investigation, it was determined that the primary criterion of utmost significance, with a priority value of 0.416 based on the AHP method, was the reliability and safety of the vessel option. Other criteria, such as operational cost, speed, fuel efficiency, route suitability/maneuverability, and serviceability, held values of 0.110, 0.098, 0.114, 0.172, and 0.090, respectively. The EDAS method was also employed in the evaluation and ranking of alternatives. Small catamarans were ranked as the best with an appraisal score of 0.9663 using the EDAS method, followed by the F-25 boat with an appraisal score of 0.9147, and the hovercraft boat was rated third with an appraisal score of 0.8476.

Keywords Marine Transportation, Inland water transportation, Vessel, Distribution of Relief Materials, AHP, EDAS

1. Introduction

A sustainable disaster supply chain has been the only viable way to mitigate the effects of spontaneous natural and man-made disasters that occur both quickly and slowly which includes saving lives, decreasing human suffering, and its need is so enormous notwithstanding its contribution to the field of disaster management [1].

In northeast Nigeria, over a ten-year humanitarian catastrophe has left 1.3 million men, 1.6 million women, 1.9 million boys, and 2.3 million girls in desperate need of aid [2].

The Northeast region has been facing protracted humanitarian crises, including conflict and natural disasters, resulting in significant logistical challenges for the efficient and timely distribution of relief materials to the affected population. By investigating maritime transportation alternatives, one can potentially identify cost-effective and reliable solutions that can enhance the speed and effectiveness of relief operations, ensuring critical aid reaches those in need promptly. Moreover, the region's geographical constraints, limited road infrastructure, and security issues necessitate exploring alternative transportation modes like maritime routes, which could offer greater accessibility and resilience in the face of potential disruptions.

Nigeria map showing the highly connected inland water that can be harnessed for national development is shown in Fig 1. 77.8% of Nigerian states can be accessed through the water while the remaining 22.2% cannot be accessed through the water [3]. With 77.8% of accessible navigational inland waterways routes, it’s important to incorporate Nigeria’s Inland Water transport system for optimal relief material distribution in northeast Nigeria. Furthermore, the inclusion of Nigeria’s inland waterway transport system in the relief material distribution channel will help in minimally reducing the pressure on other modes of transportation, especially roads in the transportation of heavy equipment and bulk goods both solid and liquid.

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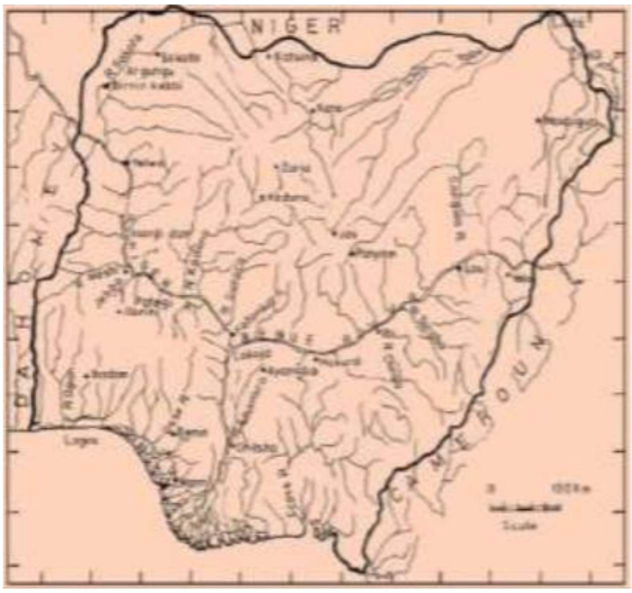

Figure 1. A highly connected inland water for Nigeria National Development. (*Source:* [3], [4],[5])

Damare IDP camp can be accessed through the river Benue, as the Northeast Humanitarian Innovation Hub which serves as the central warehouse is along the same river Benue. This study will specifically concentrate on commonly utilized marine vessels and Damare camp with its proximity to the bank of river Benue.

Ultimately, the research aims to contribute to more robust disaster response strategies and humanitarian efforts, saving lives and improving the overall well-being of vulnerable communities in Northeast Nigeria.

Nigeria's most significant rivers are the Niger-Benue and the Chad rivers with few rivers which empties immediately into the Atlantic Ocean; all other waterways eventually empty into the Chad basin or the lower Niger to the sea [6] cited in [7].

Equatorial Guinea, Chad, Niger, Cameroun, Benin, and Benin are among the five nations that Nigeria shares international borders with and they can be accessed through the inland waterway [8] cited in [3].

The Nigeria Federal navigable inland waterways as captured by [8] are as follows:

i. The River Niger from the Nigerian/Niger/Benin border, through the Nun and Forcados distributaries to the Atlantic Ocean.
ii. The River Benue from the Nigerian/Cameroun border to its confluence with River Niger at Lokoja.
iii. The Cross River from the Nigerian/Cameroun border to the Atlantic. Ocean, and all its distributaries.
iv. Rivers Sokoto. Kaduna. Geriny. Gongola. Taraba. Donga. Katsina-Ala. Anambra. Ogun. Oluwa. Osse, Benin, Imo. Kwa Ibo.
v. The Intra-coastal route from Badagry. along the Badagry Creek to Lagos through Lagos Lagoon to Epe, Lekki Lagoon to Iwopin. along Omu Creek, Talifa Kivei to Atijere, Akata. Aboto. Oluwa River to Okitipupa and to Gbekebo. Arogbo. Ofunama. Benin Creek to Warri. Also, the canal running from Araromi through Aiyetoro. Imelumo to Benin River and from Aiyetoro through Mahin Lagoon to Igbokoda.
vi. The waterway from Warri along the Forcados River, through Frukana, Siama. Bomadi. Angalabiri. Patani. Torofani. down River Nun to Agberi, Kiama. Sabagreia. Gbaran Creek, Agudama, Ekpetional into Ekole Creek to Yanaka. Yenegoa, Sangala to Mbiakpaba. onto Okokokiri, Ofokpota, Olagaga. Nembe, Adema. Agoribiri Creek to Egbema, Degema, Sombreiro River to Hanya Town, Ogbakiri to Port Harcourt.
vii. The waterway from Port Harcourt, through Amadi Creek down Bonny River, into Opobo Channel Adoni River, through Andoni Flats, Tellifer Creek, and Imo River. Shooter Creek. Kwa Ibo Creek, Kwa Ibo River, Stubbs Creeks. Widenham Creek, Effiat-Mbo Creek, Cross River estuary to Oron and Calabar.
vii. Rivers Benin. Ethiope, Ossiomo. Onne, Aba. Azumini, Olomum. Siluko, Talifa, Forcados, Penington, Escravos, Warri, Ramos, Dodo, Bonny, Middleton, Fishtown, Sengana, Brass of Nicholas, Santa Barbara. San Batholomew, Sambriero, New Calabar, Mbo, Rio del Rey, Uruan, Akwayafe.
ix. Creeks Odiama, Agamama Tora, Nembe, Krakama, Buguma, Bille, Finima, New Calabar, Ekole, Cawthprne Channel, Ikane-Bakassi, Omu, Kwato (Gwato), Adagbrassa, Chananomi, Okpoko, Jones Kulama, Ikebiri, Nikorogba, Sagbama, Egbedi, Kolo, Laylor, Hughes Channel.
x. Lakes Mahin, Oguta, Osiam Ehomu.
xi. The Orashi River from Oguta Lake to Ebocha, Omoku, Kreigani, Moiama., Okariki, Egbema, Sombreiro River.
xii. Lake Chad, that part within Nigeria.

The objective of this article is to evaluate suitable marine transportation vessel options for the efficient distribution of relief materials to the Damare IDP camp in northeast Nigeria using the enormous inland waterways in Nigeria.

[9], integrated two multi-criteria methods of Best Worst Method (BWM) and Evaluation based on Distance from Average (EDAS) in solving the site selection problem.

PESTLE (Political, Economic, Social, Technological, Legal, and Environmental) was considered to determine the optimal renewable energy consumption using fuzzy EDAS techniques [10]. [11], chose the optimal wastewater-reuse option based on the evaluation based on distance from the average solution for grey water (EDAS-G) after the criteria were weighed using the analytical hierarchy process (AHP) approach. [12], AHP weights the sustainable factors while using fuzzy EDAS and fuzzy Topsis for ranking of improvement set to determine application priority. Therefore, AHP and EDAS will be applied to evaluate suitable marine transportation vessel options for the efficient distribution of relief materials to the Damare IDP camp in northeast Nigeria.

2. Methodology

In this study, AHP and EDAS have been employed for the aim of ranking marine vessel alternatives concerning the precedence order in the criteria. AHP is used for the construction of an evaluation matrix while EDAS is used in calculating the weighted sum of PDA, normalized values of the weighted sum of the NDA, appraisal, and ranking of alternatives.

2.1. Analytical Hierarchy Process (AHP)

Practically, the applications of the AHP approach by [13] gave way to the introduction of the technique as a weight-estimating tool and a way for solving multi-criteria decision-making.

With the help of matrices and linear algebra, the Analytic Hierarchy Process (AHP) is a multi-step decision analysis model known for transforming qualitative factors into quantitative measures where each criterion is given a weight that causes it to differ from the others based on importance, and this principle is used to assess alternatives [14].

Determination of the relative importance of each pair of criteria in the same hierarchy is the first step in applying the AHP approaches, completing the pairwise comparison, and building of evaluation matrix. Table 1 shows the AHP scale used in this study.

Table 1. Saaty's 1-9 Scale of Pairwise Comparisons

Rating	Definition	Explanation
1	Equal Importance	Two activities contributes equally to the objective
2	Weak or Slight	
3	Moderate Importance	Experience and judgement slightly favors one activity over another
4	Moderate Plus	
5	Strong Importance	Experience and judgement strongly favors one activity over another
6	Strong Plus	
7	Very Strong	An activity is favoured very strong over another
8	Very Very Strong	
9	Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation

Source: [13]

The steps involved in the AHP method are described as follows:

Step 1: Construct a pair-wise comparison matrix of the chosen criteria using the AHP scale. If there is more than one expert involved in the pair-wise comparison exercise the average rating can be obtained using the formula below:

$$\frac{\sum_{i=1}^{n} a_i}{n} \quad (1)$$

Where a_i = value estimated by expect for a criterion

n = total number of experts involved in the pair-wise comparison exercise.

Step 2: Representation of the average numerical value ratings in a crisp value matrix

Step 3: Computation of criteria weights using Equation 2

$$w_j = \frac{1}{n} \sum_{j=1}^{n} \left(\cdot \frac{a_{kj}}{\sum_{i=1}^{n} a_{ij}} \right) \quad (2)$$

Where n = Number of criteria

W_j = The criteria's weight

a_{ij} = The entry in row I and colum j in the pair-wise comparison matrix for each criteria

N = Matrix ord

2.2. Evaluation Based on Distance from Average Solution (EDAS) Method

The EDAS method was developed by [15]. The approach is highly effective when dealing with conflicting attributes. It involves ranking alternatives by their proximity to the average solution. This is accomplished through two measures: Positive Distance from Average (PDA) Solution and Negative Distance from Average (NDA) Solution. The best alternative is determined by a high PDA value and a comparatively lower NDA value. The computation steps for the EDAS method are detailed as outlined in [15].

Step 1: Choosing the criteria and the options, a decision matrix labeled as x is created, as depicted.;

$$X = \begin{bmatrix} x_{11} & x_{12} \dots\dots & x_{1n} \\ x_{12} & x_{22} \dots\dots & x_{2n} \\ x_{1n} & x_{2n} \dots\dots & x_{mn} \end{bmatrix} \quad (3)$$

where denotes the performance evaluation of the particular alternative *i* on the criterion *j*. It is considered that all x_{ij} are positive real numbers.

Step 2: Calculating the average solution utilizing Equation (5) (6) across all criteria.

$$x_j^* = \frac{\sum_{k=1}^{m} x_{ij}}{m} \quad (4)$$

where *m* denotes the number of alternatives.

Step 3: Compute the negative distance from the average solution (NDA) and the positive distance from the average solution (PDA) by utilizing Equations (5), (6), (7) and (8) respectively based on the beneficial and non-beneficial criteria.

$$d_{ij}^- = \frac{\max(0, (x_j^* - x_{ij}))}{x_j^*} \text{......}; j \in \cap_{\max} \quad (5)$$

$$\frac{\max(0, (x_{ij} - x_j^*))}{x_j^*} \text{......}; j \in \cap_{\min} \quad (6)$$

$$d_{ij}^{+} = \frac{\max(0,(x_{ij} - x_j^{*}))}{x_j^{*}} \text{......}; j \in \cap_{\max} \quad (7)$$

$$\frac{\max(0,(x_j^{*} - x_{ij}))}{x_j^{*}} \text{......}; j \in \cap_{\min} \quad (8)$$

where $\cap_{\max}$ and $\cap_{\min}$ respectively denote the sets of beneficial and non-beneficial criteria, and x_j^* represent a positive number.

Step 4: Calculate the weighted sum of PDA, Q_i^+ and the weighted sum of NDA Q_i^-, for all alternatives using a vector w ($w_1, w_2, w_2, \ldots\ldots w_n$) comprising non-negative weights.

$$Q_i^{+} = \sum_{j-1}^{n} w_j d_{ij}^{+} \quad (9)$$

$$Q_i^{-} = \sum_{j=1}^{n} w_j d_{ij}^{-} \quad (10)$$

where w_j denotes the weight of the criteria.

Step 5: Calculate the normalized values of the weighted sum of the NDA and the weighted sum of the PDA for evaluated alternatives through the utilization of Equations 11 and 12

$$S_i^{-} = 1 - \frac{Q_i^{-}}{\max_i Q_i^{-}} \quad (11)$$

$$S_i^{+} = \frac{Q_i^{+}}{\max_i Q_i^{+}} \quad (12)$$

where s_i^- and s_i^+ respectively denote the normalized weighted sum of the NDA and the weighted sum of the PDA.

Step 6: Calculation of the appraisal score s_i for evaluated alternatives utilizing Equation (13).

$$S_i = \frac{1}{2}(S_i^{+} + S_i^{-}) \quad (13)$$

Step 7: Rank the alternative. The alternative possessing the greatest value of s_i is regarded as the most favorable.

2.3. Application of AHP – EDAS approach in Evaluate Suitable Marine Transportation Vessel Options for the Efficient Distribution of Relief Materials to the Damare IDP camp in Northeast Nigeria

This section examines the pertinent factors that should be taken into account for the best possible transportation of relief supplies to internally displaced persons camps in Northeastern Nigeria. These factors are based on variables that have a direct impact on the efficient transportation of relief materials and marine vessel transportation options, with inland navigable waterways serving as a crucial component of marine transportation that is utilised for the last-mile distribution of relief supplies to communities and IDP camps along the coastline or riverbanks.

2.4. Criteria Descriptions

The criteria are divided into two components Cost and Safety. However, there are six criteria to be considered which are Cost-effectiveness (C), Speed/Transit Duration (SP), Fuel Efficiency (FE), Route suitability/Maneuverability (RM), Reliability and Safety (RS), and Serviceability (S). Some of these criteria have both cost and safety components like Route suitability/ Maneuverability (RM) and Speed/ Transit Durations. However, Cost-effectiveness (C), Speed/ Transit Duration (SP), and Serviceability (S) are the cost components while Route Suitability/Maneuverability (RM), Speed/Transit Duration (SP), and Reliability and Safety (RS) are the Safety components of the criteria.

2.5. Vessels Alternative Descriptions

Nine marine craft alternatives that can operate in the northeast region of Nigeria were considered. The crafts have an average draft between 2meters to 5meters. Which gives them the advantage of operating in River Benue in northeast Nigeria. The following are the marine vessel alternatives been considered for the efficient and optimal distribution of relief materials:

1. Automated Underwater Vehicle (AUV
2. Dinghies
3. Pontoon boat
4. Ferries
5. Hovercraft boat
6. Kayaks and Canoes
7. F-25 Boat
8. Small Catamarans
9. Tug Boat

3. Results and Discussions

3.1. Application of AHP for Criteria's Weight Determination

Taking separate weights out, a pairwise comparison of criteria was carried out to evaluate suitable marine transportation vessel options for the efficient distribution of relief materials to the Damare IDP camp in northeast Nigeria.

Three Experts were enlisted in this study to conduct the pair-wise comparison, and their involvement is presented in Table 2 used in developing a performance evaluation model that integrates various criteria. The AHP pairwise criteria performance design was done using Saaty's 1-9 Scale of Pairwise Comparison in Table 1.

Table 2. Pairwise Comparison of Criteria

Pairwise comparison		Important criteria	Expert #1 Estimate	Expert #2 Estimate	Expert #3 Fuzzy Estimate	Aggregation of Experts' Estimate	Division of aggregated estimate by total number of experts
C	SP	C/SP	1	1	1	3	1
C	FE	C	3	4	4	11	3.7
C	RM	RM	4	3	4	11	3.7
C	RS	RS	5	6	6	17	5.7
C	S	C/S	1	1	1	3	1
SP	FE	FE	2	2	2	6	2
SP	RM	RM	1	3	2	6	2
SP	RS	RS	2	1	3	6	2
SP	S	S/SP	1	1	1	3	1
FE	RM	FE	3	2	1	6	2
FE	RS	RS	6	6	5	17	5.7
FE	S	S	3	1	2	6	2
RM	RS	RS	4	4	4	16	4
RM	S	RM	3	2	4	9	3
RS	S	RS	6	5	6	17	5.7

Source: Computed by Authors (2023)

Table 3. Vessel's Criteria Crip Value Matrix

CRITERIA	C	SP	FE	RM	RS	S
C	1	1	3.7	1/3.7	1/5.7	1
SP	1	1	½	½	1/2	1
FE	1/3.7	2	1	2	1/5.7	1/2
RM	3.7	2	½	1	1/4	3
RS	5.7	2	5.7	4	1	5.7
S	1	1	2	1/3	1/5.7	1
Sum	12.67	9	13.40	8.10	2.28	12.2

Source: Computed by Authors (2023)

The weights of the criteria were calculated using Equation 2, $w_j = \frac{1}{n} \sum_{j=1}^{n} \left(\cdot \frac{a_{kj}}{\sum_{i=1}^{n} a_{ij}} \right)$ Where n is the matrix order, which is represented as 6, a_{ij} is the entry in row in the pair-wise crisp matrix for each criteria. The summation of the values obtained as the result of the division of each entry value in the column by the sum of the total entry value were multiplied by 1/6 which represented the matrix order to obtain the weight.

Table 3 is a vessel criteria crip value matrix drawn from pair wise comparison of criteria table 2 as responded by each expert judgement. The sum of each column was computed.

Weight of C= 1/6 [1/12.67 + 1/9 + 3.7/13.40 + 0.2703/8.10 + 0.1754/2.28 + 1/12.2]
=1/6 [0.0789 + 0.1111 + 0.2761 + 0.0334 + 0.0769 + 0.0820]
= 1/6 [0.6584]
= 0.110

Weight of SP= 1/6 [1/12.67 + 1/9 + 0.5/13.40 + 0.5/8.10 + 0.5/2.28 + 1/12.2]
=1/6 [0.0794 + 0.1111 + 0.0373 + 0.0617 + 0.2193 + 0.0820]
= 1/6 [0.5908]
= 0.098

Weight of FE = 1/6 [0.2703/12.67 +2/9 + 1/13.40 + 2/8.10 + 0.1754/2.28 + 0.5/12.2]
=1/6 [0.0213 + 0.2222 + 0.0746 + 0.2469 + 0.0769 + 0.0410]
= 1/6 [0.6829]
= 0.114

Weight of RM = 1/6 [3.7/12.67 +2 /9 + 0.5/13.40 + 1/8.10 + 0.25/2.28 + 3/12.2]
=1/6 [0.2920 + 0.2222 + 0.0373 + 0.1235 + 0.1096 + 0.2459]
= 1/6 [1.0305]
= 0.172

Weight of RS= 1/6 [5.7/12.67 + 2/9 + 5.7/13.40 + 4/8.10 + 1/2.28 + 5.7/12.2]
=1/6 [0.4499 + 0.2222 + 0.4254 + 0.4938 + 0.4386 + 0.4672]
= 1/6 [2.4971]
= 0.416

Weight of S= 1/6 [1/12.67 + 1/9 + 2/13.40 + 0.3333/8.10 + 0.1754/2.28 + 1/12.2]
=1/6 [0.0789 + 0.1111 + 0.1493 + 0.0411 + 0.0769 + 0.0820]
= 1/6 [0.5393]
= 0.090

3.2. Application of EDAS Method for Alternatives' Evaluation and Ranking

The EDAS method employed the predetermined criteria weight obtained using the AHP method in the evaluation and ranking of the vessel alternatives for relief material distribution to the Damare IDP camp in northeast Nigeria. The average experts rating values were obtained as shown in Table (4)

Table 4. Rating of Vessel alternatives

Alternatives	Criteria					
	C	SP	FE	RM	RS	S
Automated Underwater Vehicle	7	4	9	1	8	5
Tugboat	6	3	4	7	7	6
F-25 Boat	4	9	6	7	6	7
Dinghies	2	3	8	6	5	9
Small catamarans	3	7	7	6	7	6
Pontoon boat	2	2	5	5	6	8
Ferries	8	3	4	6	7	5
Hovercraft boat	6	8	4	7	7	6
Kayaks and Canoes	1	1	9	5	3	9
Avj	4.3	4.4	6.2	5.6	6.2	6.8

Source: Computed by Authors (2023)

The positive distance from the average rating value was determined for each alternative using Equation (9) for beneficial criteria by subtracting the average value from the rated value, the result was divided by the average value. Negative value as a result of the division was presented as zero (0). This was done for each column to obtain the result presented in Table 5.

For non-beneficial criteria (cost), the positive distance from the average rating value was determined for each alternative using Equation (10) by subtracting the rated value from the average value, the result was divided by the average value. Negative value as a result of the division was presented as zero (0).

Table 5. Positive Distance from Average (PDA)

Alternatives	Criteria					
Weight	0.110	0.098	0.114	0.172	0.416	0.090
	C	SP	FE	RM	RS	S
Automated Underwater Vehicle	0	0	0.45	0	0.29	0
Tugboat	0	0	0	0.25	0.13	0
F-25 Boat	0.07	1.05	0	0.25	0	0.03
Dinghies	0.53	0	0.29	0.07	0	0.32
Small catamarans	0.30	0.59	0.13	0.07	0.13	0
Pontoon boat	0.53	0	0	0	0	0.18
Ferries	0	0	0	0.07	0.13	0
Hovercraft boat	0	0.82	0	0.25	0.13	0
Kayaks and Canoes	0.77	0	0.45	0	0	0.32

Source: Computed by Authors (2023)

The weighted sum of the positive distance from the average rating value was determined for each alternative using Equation 11. The obtained values in each column were multiplied with their respective weights to obtain the results presented in Table 6. The Q_i^+ is the sum of all the values in the row.

The negative distance from the average rating value was determined for each alternative using Equations 7 for beneficial criteria by subtracting the rated value from the average value, the result was divided by the average value. Negative value as a result of the division was presented as zero (0). For non-beneficial criteria (cost), the negative distance from the average value was determined for each alternative using Equation 8 by subtracting the average value from the rated value, the result was divided by the average value. Negative value as a result of the division was presented as zero (0). This was done for each columns to obtain the result presented in Table 7.

Table 6. Weighted Sum of PDA

Alternatives	Criteria						
	C	SP	FE	RM	RS	S	Q_i^+
Automated Underwater Vehicle	0	0	0.0513	0	0.1206	0	0.1719
Tugboat	0	0	0	0.0430	0.0541	0	0.0971
F-25 Boat	0.0077	0.1029	0	0.0430	0	0.0027	0.1563
Dinghies	0.0583	0	0.0331	0.0120	0	0.0288	0.1322
Small catamarans	0.0330	0.0578	0.0148	0.0120	0.0541	0	0.1717
Pontoon boat	0.0583	0	0	0	0	0.0162	0.0745
Ferries	0	0	0	0.0120	0.0541	0	0.0661
Hovercraft boat	0	0.0804	0	0.0430	0.0541	0	0.1775
Kayaks and Canoes	0.0847	0	0.0513	0	0	0.0288	0.1648

Source: Computed by Authors (2023)

Table 7. Negative Distance from Average (NDA)

Alternatives	Criteria					
Weight	0.110	0.098	0.114	0.172	0.416	0.090
	C	SP	FE	RM	RS	S
Automated Underwater Vehicle	0.63	0.09	0	0.82	0	0.26
Tugboat	0.40	0.32	0.35	0	0	0.12
F-25 Boat	0	0	0.03	0	0.03	0
Dinghies	0	0.32	0	0	0.19	0
Small catamarans	0	0	0	0	0	0.12
Pontoon boat	0	0.55	0.19	0.11	0.03	0
Ferries	0.86	0.32	0.35	0	0	0.26
Hovercraft boat	0.40	0	0.35	0	0	0.12
Kayaks and Canoes	0	0.77	0	0.11	0.52	0

Source: Computed by Authors (2023)

Table 8. Weighted Sum of NDA

Alternatives	Criteria						
	C	SP	FE	RM	RS	S	**Q_i^-**
Automated Underwater Vehicle	0.0693	0.0088	0	0.1410	0	0.0234	0.2425
Tugboat	0.0440	0.0314	0.0399	0	0	0.0108	0.1261
F-25 Boat	0	0	0.0034	0	0.0125	0	0.0159
Dinghies	0	0.0314	0	0	0.0790	0	0.1104
Small catamarans	0	0	0	0	0	0.0108	0.0108
Pontoon boat	0	0.0539	0.0217	0.0189	0.0125	0	0.1070
Ferries	0.0946	0.0314	0.0399	0	0	0.0234	0.1893
Hovercraft boat	0.0440	0	0.0399	0	0	0.0108	0.0947
Kayaks and Canoes	0	0.0755	0	0.0189	0.2163	0	0.3107

Source: Computed by Authors (2023)

Table 9. Alternative Ranking

Alternatives	**Q_i^+**	**Q_i^-**	**S_i^+**	**S_i^-**	**$S_i^{|}$**	**RANK**
Small catamarans	0.1717	0.0108	0.9673	0.9652	0.9663	1
F-25 Boat	0.1563	0.0159	0.8806	0.9488	0.9147	2
Hovercraft boat	0.1775	0.0947	1.0000	0.6952	0,8476	3
Dinghies	0.1322	0.1104	0.7448	0.6447	0.6948	4
Automated Underwater Vehicle	0.1719	0.2425	0.9685	0.2195	0.5940	5
Tugboat	0.0971	0.1261	0.5470	0.5941	0.5706	6
Pontoon boat	0.0745	0.1070	0.4197	0.6556	0.5377	7
Kayaks and Canoes	0.1648	0.3107	0.9285	0	0.4643	8
Ferries	0.0661	0.1893	0.3724	0.3907	0.3816	9

Source: Computed by Authors (2023)

The weighted sum of the negative distance from the average rating value was determined for each alternative using Equation 12. The obtained values in each column were multiplied with their respective weights to obtain the results presented in Table 8. The Q_i^- is the sum of all the values in the row.

The normalization of the values of the weighted sum of the positive distance from the average rating value and the negative distance from the average rating value were determined using Equation 12 and Equation 13 respectively. The normalized value of $Q_i^+$was obtained by dividing each value of Q_i^+ by the maximum value of Q_i^+ in the column to obtain the value of S_i^+. The normalized value of Q_i^- was obtained by subtracting the value of Q_i^- from 1, and dividing it with the maximum value of Q_i^- to obtain the value of S_i^-.

The appraisal score (S_i) for all considered alternatives were obtained using Equation 13, by dividing the sum of S_i^+ and S_i^- by two. The alternatives were ranked based on decreasing values of the appraisal score as presented in Table 9 with Small catamarans toping followed by F-25 boat, hovercraft boat, Dinghies, Automated Underwater Vehicle, Tugboat, Pontoon Boat, Kayaks and canoes while the least in ranking alternatives are ferries.

AHP pairwise comparison was used in the development of a performance evaluation model that integrates various criteria. However, reliable data and practical experience were both incorporated into the evaluation model to facilitate effective decision-making using the team of experts as in Table 2 and Table 3 respectively. EDAS was used in computing the average solution, computing the negative distance from the average solution (NDA) and the positive distance from the average solution (PDA), compute the appraisal score and finally rank alternatives with Equation 3 to 13.

In addition, the various options assessed, small catamarans emerged as the most advantageous choice. They exhibited remarkable benefits compared to other alternatives, showcasing superior speed, fuel efficiency, dependability, and safety. The assessment involved a comparison of vessel alternatives based on six essential criteria: Operational Costs, Fuel Efficiency, Route Suitability and Maneuverability, Reliability and safety, Maintainability, and Speed. The findings of the assessment highlighted that Reliability & Safety and route maneuverability hold the utmost significance in selecting the appropriate vessel type for relief material distribution.

4. Conclusions

The AHP-EDAS methodology was employed this study was dedicated to evaluating the most suitable marine transportation vessel options for the efficient distribution of relief materials to the Damare IDP camp in northeast Nigeria. These methodologies encompass criteria selection, data collection, information integration, evaluation, and the assessment of vessel alternatives. The strength of these models lies in their capacity to analyze disparate, incomplete, and definite data from multiple information sources. The advantage of these integrated approaches is their ability to ensure reliable and consistent benchmarking. Moreover, the integrated approaches involved a panel of maritime transportation experts, whose active engagement contributes to a well-rounded consideration of requirements for both criteria and alternatives. Consequently, the proposed methodology surpasses conventional approaches to vessel selection.

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