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A FUZZY HYBRID DECISION SUPPORT SYSTEM FOR INTERCEPTOR BAYWATCH BOAT PROPULSION SYSTEM SELECTION

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Preliminary notes

Decision support systems are rapidly gaining more importance in every field of science and technology especially when the problems to be solved are complicated including many criteria that affect the solution and the decision making process. Fuzzy set theory and fuzzy logic based decision models have properly begun to occupy a broad place in decision support models in recent years. In this study, a decision support model for the propulsion system selection for a light interceptor Baywatch boat is proposed and the application of the proposed model in Turkish maritime sector is performed using a fuzzy hybrid decision support software (DESTEC.01) which enables the decision maker to use Analytic Hierarch Process, Fuzzy Analytic Hierarchy Process, Analytic Network Process, and Fuzzy Analytic Network Process separately or all at once.

Keywords: *DSS, FAHP, FANP, interceptor Baywatch boat, propulsion system selection*

Neizrazito hibridni sustav za potporu odlučivanju pri izboru pogonskog sustava za brod presretač

Prethodno priopćenje

Sustavi za podršku odlučivanju postaju sve važniji u svakom području znanosti i tehnologije posebno kad su problemi koje treba riješiti komplicirani i uključuju mnoge kriterije koji utječu na rješenje i proces donošenja odluke. Modeli odlučivanja zasnovani na teoriji neizrazitog skupa i neizrazite logike su s pravom počeli zauzimati važno mjesto u modelima za podršku odlučivanju u posljednjih nekoliko godina. U ovom se radu predlaže model za podršku odlučivanju pri odabiru pogonskog sustava za laki brod presretač te se vrši primjena predloženog modela u turskom pomorskom sektoru uz pomoć softvera za neizrazito hibridni sustav za potporu odlučivanju (DESTEC.01) koji omogućuje donosiocu odluke da koristi Analytic Hierarchy Process, Fuzzy Analytic Hierarchy Process, Analytic Network Process, and Fuzzy Analytic Network Process odvojeno ili sve od jednom.

Ključne riječi: *brod presretač u zaljevu, DSS, FAHP, FANP, izbor pogonskog sustava*

1 Introduction

Decision making is an important and hard process especially when the problem concerned includes multi criteria and also if the result of the problem will influence a broad area. If the decision making process includes more than one criterium it is called Multi Criteria Decision Making (MCDM) and in this situation decision making gets more confused [1]. In this study, a decision support model (DSM) for determining the appropriate propulsion system for a light interceptor baywatch boat (IBB) is proposed and its application is performed by a fuzzy based hybrid decision support software (DSS) that is developed using C Sharp programming language and named as "Decision Support Tool for Enhanced Choose" (DESTEC.01) which enables the decision maker to use Analytic Hierarchy Process (AHP), Fuzzy AHP, Analytic Network Process (ANP) and Fuzzy ANP all at once or separately. In Section 2, AHP, FAHP, ANP, FANP methods are explained briefly, in Section 3 developed DSS is introduced, in Section 4 the proposed DSM for IBB propulsion system selection is described and its application in Turkish Maritime sector is illustrated.

2 Methodology

2.1 Analytic Hierarchy Process (AHP)

AHP is one of the most generally accepted MCDM methods which was introduced to the literature by Saaty in 1970's [2, 3, 4]. AHP uses eigenvalue method in order to obtain priorities of the criteria and alternatives, by pairwise matrices which compare the hierarchical elements of the decomposed problem. Not only the problem definition and establishing the hierarchy but also comparing the elements in the pairwise matrices should be done by experts of that field to achieve a consistent and a reasonable result. The aim of the method is to determine the priorities of the criteria and how each alternative meets each criterion. The methodology of AHP can briefly be explained as follows [2, 4, 5]:

1. Define the problem. Determine your criteria (and sub-criteria, if there are any).
2. Make the comparison matrix for criteria (pairwise matrix). Compare main criteria among themselves, and then compare sub-criteria for each main criterion and get priority vectors. Priority vector is obtained by eigenvalue formulation. In this formulation A is the pairwise matrix, is the maximum eigenvalue for pairwise matrix and w is the priority vector [2]. Following this calculation the priority of each sub-criterion is multiplied with the priority of its parent criterion so the global priorities of each criterion which will be used to compare alternatives are obtained.
3. Check the consistency of the pairwise matrices. If consistency is greater than 0,1 rebuild the pairwise matrices because the comparisons you made in the matrix are not consistent [2].
4. Make comparison matrices for comparing alternatives for each sub-criterion and find priorities.
5. Multiply the priority of each alternative for each criterion and the priority of the criterion and the sum of all these priorities for each alternative gives us the global priority of each alternative.

In AHP comparisons are made using the scale in Tab. 1 [2, 4, 5].

In AHP the problem structure is in the form of hierarchy as illustrated in Fig. 1.

Table 1 Scale used in AHP

Intensity of Importance	Definition
1	Equal Importance
2	Weak or slight
3	Moderate importance
4	Moderate plus
5	Strong importance
6	Strong plus
7	Very strong or demonstrated importance
8	Very, very strong
9	Extreme importance

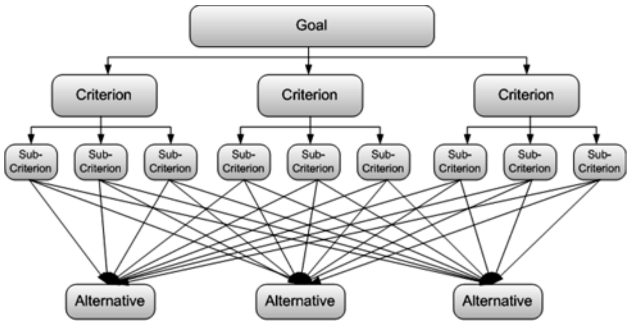

Figure 1 Hierarchical Model Used in AHP

2.2 Analytic Network Process (ANP)

ANP which is developed by Thomas Saaty is a "general theory or relative measurement used to derive composite priority ratio scales from individual ratio scales that represent relative measurements of the influence of elements that interact" [6]. In AHP models as in Fig. 1, the criteria and alternatives are in a hierarchical form. But in ANP, the structure of the problem is stated in a network form with nodes and arcs as in Fig. 2. This network includes clusters containing the homogeneous criteria, and nodes (criteria themselves). The arcs show the effect between the clusters. These arcs occur according to the influences betweens nodes. If a node is influenced by a node in another cluster, it means that the first cluster is dependent on the second and the arc goes from first to second node (criterion) [7]. This is called "outer dependence". Sometimes a node can be affected by another one in the same cluster. In this situation an inner dependence occurs as in the cluster 3 illustrated in Fig. 2. If two clusters are dependent on each other it is called feedback [8].

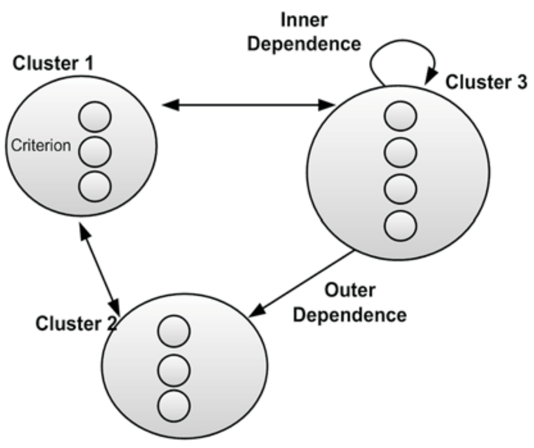

Figure 2 ANP Network Model

So in this method, the consideration of the effects between criterion and alternatives is possible and the method gives more reasonable results if the clusters in the problem have dependence and feedback. Here the effects in lateral can also be shown.

The steps of ANP can briefly be stated as follows.

1. Determine the criteria, alternatives and make clusters and indicate influences. So establish the network structure of the problem.
2. Make pairwise matrices for each criterion (node) containing the effecting criteria for each cluster. In pairwise matrices the same comparison table in AHP is used, and the priority vectors are calculated in the same way. Here alternatives are treated as other criteria in the problem. Then the cluster matrix is established which includes information about how each cluster influences the others.
3. Establish un-weighted supermatrix using priority vectors of the pairwise matrices established for each criterion. Then in this supermatrix multiply every cluster block with the element corresponding that block in the cluster matrix and obtain the weighted supermatrix.
4. Following this find the limiting matrix by getting powers of weighted supermatrix. (If limiting matrix cannot be achieved by getting the powers of the matrix, use Cesaro Sum method [8, 9].
5. In limit matrix all columns are the same and the values in the lines show the global priority of each criterion for the network. Here, the local priorities of alternatives (as any other criterion) by normalizing the priorities of alternatives in alternatives cluster could be determined.

2.3 Fuzzy AHP and Fuzzy ANP

Fuzzy set theory is first presented to the literature by Zadeh in 1965 [10]. Zadeh defined the fuzzy set as "a class of objects with a continuum of grades of membership" [10]. In crisp sets the membership of the elements is represented by 0 and 1. 0 means the element is not a member of the set while 1 means the element is the member of the defined set. But in the fuzzy sets, every element has its own membership degree according to the membership function. The membership degree is a value between 0 and 1, including them. 0 means the element is exactly not a member and 1 shows the strongest membership for the set [4, 5, 11]. The intermediate values between 0 and 1 grade of the membership with respect to the strongest membership value 1. The following figure illustrates one of the most common membership functions, the triangular membership function.

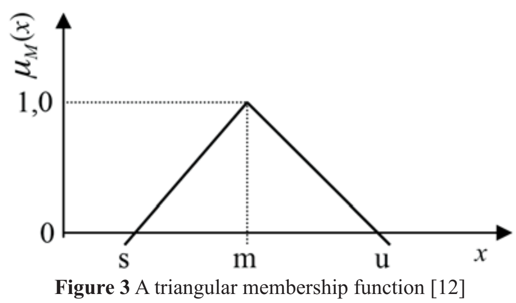

Figure 3 A triangular membership function [12]

Here, 's' is the smallest possible value, 'm' is the most promising value and 'u' is the largest possible value [12].

In the literature there exist many methods developed for FAHP but among all, the most widely used is the "Chang's Synthetic Extent FAHP" method [13, 14] due to its simplicity. In FAHP and FANP the priority vectors are derived from pairwise matrices with the help of fuzzy methods. Other calculations in FAHP and FANP are the same as AHP and ANP. The calculation of priority vectors from pairwise matrices in Chang's extent analysis method can be summarized as follows [11, 12, 13, 14]: Determine the pairwise matrix using Tab. 2 (There are also other scales, but in this study Chen's scale [15] is used as illustrated in Tab. 2). Let $X=\{x_1,x_2,x_3,...,x_n\}$ be the object set and $G=\{g_1,g_2,g_3,...,g_m\}$ the goal set. In this method for each goal i extent analysis is performed for each object j, and following m extent analysis values are obtained as

$$M_{g_i}^1, M_{g_i}^2, M_{g_i}^3,..., M_{g_i}^m,\ i=1,2,3,...,n \tag{1}$$

where the $M_{g_i}^m$'s are triangular fuzzy numbers (TFNs).
Step 1: Fuzzy synthetic extent value for each object i is

$$S_i=\sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1}. \tag{2}$$

To obtain $\sum_{j=1}^{m} M_{g_i}^j$ perform a fuzzy addition operation of m extent analysis values for a particular matrix as

$$\sum_{j=1}^{m} M_{g_i}^j=\left(\sum_{j=1}^{m} l_i, \sum_{j=1}^{m} m_i, \sum_{j=1}^{m} u_i\right), \tag{3}$$

and to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1}$ perform the fuzzy addition operation of $M_{g_i}^j,\ (i=1,2,...,m)$ values using equation (4)

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j=\left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right). \tag{4}$$

Compute the inverse of the vector in the equation (6) such that:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1}=\left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right). \tag{5}$$

Table 2 Chen's Comparison Scale for FAHP [15]

	TFN	Reciprocal of TFN
Equal Importance	(1, 1, 2)	(1/2, 1,1)
Weak or slight	(1, 2, 3)	(1/3, 1/2, 1)
Moderate importance	(2, 3, 4)	(1/4, 1/3, 1/2)
Moderate plus	(3, 4, 5)	(1/5, 1/4, 1/3)
Strong importance	(4, 5, 6)	(1/6, 1/5, 1/4)
Strong plus	(5, 6, 7)	(1/7, 1/6, 1/5)
Very strong or demonstrated importance	(6, 7, 8)	(1/8, 1/7, 1/6)
Very, very strong	(7, 8, 9)	(1/9, 1/8, 1/7)
Extreme importance	(8, 9, 9)	(1/9, 1/9, 1/8)

Step 2: For two fuzzy numbers $M_1(l_1,m_1,u_1)$ and $M_2(l_2,m_2,u_2)$, the degree of possibility $M_2 \geq M_1$ can be defined as:

$$V(M_2 \geq M_1)=\sup_{y\geq x}\left[\min(\mu_{M_1}(x), \mu_{M_2}(y))\right] \tag{6}$$

$$V(M_2 \geq M_1)=\mathrm{hgt}(M_1 \cap M_2)=\mu_{M_2}(d)= \\ =\begin{cases} 1, & \text{if } m_2 \geq m_1 \\ 0, & \text{if } l_1 \geq u_2 \\ \dfrac{l_1-u_2}{(m_2-u_2)-(m_1-l_1)}, & \text{otherwise} \end{cases} \tag{7}$$

where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2} (Fig. 4).

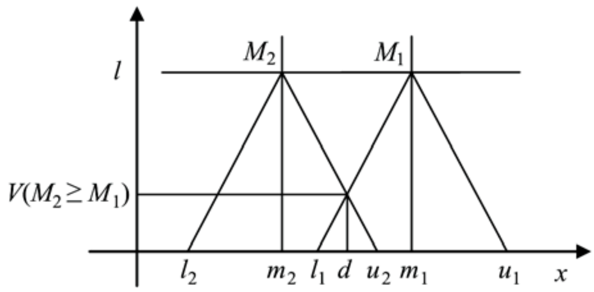

Figure 4 Triangular membership function [11]

Step 3: The degree possibility for k convex fuzzy number $M_i, (i=1,2,3,...,k)$ can be defined as

$$V(M \geq M_1, M_2,...,M_k)= \\ =V[(M \geq M_1) \text{ and } (M \geq M_2) \text{ and ... and } (M \geq M_k)]= \\ =\min V(M \geq M_i), i=1,2,...,k. \tag{8}$$

Assuming the following relation:

$$d'(A_i)=\min V(S_i \geq S_k), \tag{9}$$

for $k=1,2,...,n;\ k\neq i$, then weight vector can be written as

$$\boldsymbol{W}'=(d'(A_1), d'(A_2),..., d'(A_n))^{\mathrm{T}}, \tag{10}$$

where $A_i (i=1,2,...,n)$ are n elements.

Step 4: Via normalization, the normalized weight vectors are

$$\boldsymbol{W}=(d(A_1), d(A_2),..., d(A_n))^{\mathrm{T}}, \tag{11}$$

where $\boldsymbol{W}$ is a non-fuzzy vector [11]. This non-fuzzy vector is to be used in further calculations as in AHP and ANP.

3 Decision Support Tool for Enhanced Choose (DESTEC 1.0)

DSSs are in literature since early 70's and still developing rapidly with the computer technology [16]. DSSs are software based tools which are used by organizations for making decision making activities stronger and more effective [16, 17].The DSS introduced in this study (DESTEC 1.0) is developed using Microsoft Visual C# programming language, which helps decision makers to use AHP, FAHP, ANP, and FANP at the same time up to three level problem structure which means that the DESTEC 1.0 can hold main criteria, sub-criteria and sub-sub-criteria including alternatives. This software uses Microsoft Excel to read input data. To use DESTEC 1.0, user needs to enter criteria and alternatives into the Excel sheet opened in the required form by the software as illustrated in Fig. 5. In this data input sheet, the yellow cells are for main criteria, greens are for sub-criteria and blues are for sub-sub-criteria.

	A	B	C	D	E	F	G
1	GOAL	0	PROPULSION SYSTEM SELECTION				
2	CRITERIA	100	Cost		sub-sub-criteria		
3	sub-criteria	110	Initial Cost	111		112	
4		120	Maintenance Cost	121		122	
5		130	Fuel Cons Cost	131		132	
6		140		141		142	
7		150		151		152	
8		160		161		162	
9		170		171		172	
10		180		181		182	
11		190		191		192	
12	CRITERIA	200	Performance		sub-sub-criteria		
13	sub-criteria	210	Max Speed	211		212	
14		220	Cruise speed	221		222	
15		230	Maneuver Cap	231		232	
16		240	Heavy Sea State	241		242	
17		250		251		252	
18		260		261		262	
19		270		271		272	
20		280		281		282	
21		290		291		292	
22	CRITERIA	300	Maintenance		sub-sub-criteria		
23	sub-criteria	310	Repair for Shallow Water Brea	311		312	
24		320	Maintenance Ease	321		322	
25		330	Maintenance frequency	331		332	
26		340		341		342	
27		350		351		352	

Criteria / Influences / pairWiseMatrices

Figure 5 DESTEC 1.0 data input Excel sheet (Criteria)

The table also contains the numbers of each criterion. As an example, "111" represents the sub-sub-criterion under the first main criterion "100" first sub-criterion "110". The table is able to hold 9 main criteria, 9 sub-criteria for each main criterion, 9 sub-sub criteria for each sub-criterion, and 9 alternatives. Alternatives are at the bottom of the sheet in pink color cells as illustrated in Fig. 6. After entering the criteria, the software opens a table for the entry of the influences between criteria that is used in for calculations of ANP and FANP for the user who wants also to use those models for the defined problem. As illustrated in Fig. 7, the table shows the influenced criteria at the top of the columns, and the influencing criteria on the left of the rows. If a criterion at the top is dependent on (influenced by) a criterion on the row, "1" is entered as the value in the cell at the transaction of these two criteria.

	A	B	C	D	E	F	G
82	CRITERIA	900			sub-sub-criteria		
83	sub-criteria	910		911		912	
84		920		921		922	
85		930		931		932	
86		940		941		942	
87		950		951		952	
88		960		961		962	
89		970		971		972	
90		980		981		982	
91		990		991		992	
92	ALTERNATIVES	1000	Alternatives				
93		1001	Jet Drive				
94		1002	Surface Drive				
95		1003	Stern Drive				
96		1004					
97		1005					
98		1006					
99		1007					
100		1008					
101		1009					

Figure 6 DESTEC 1.0 data input Excel sheet (Alternatives)

If there is no influence the cell will be left empty. In the example illustrated in Fig. 7, the criterion "max speed" depends on "fuel consumption cost", "maneuver capability" and "heavy sea state". After this stage, user has to fill out the pairwise matrices that are formed according to the criteria and influences by the software. DESTEC 1.0 also calculates and illustrates the consistency ratio of each matrices, and in case of inconsistency (when the ratio is over 0,1) gives a warning for the user. After the matrices are filled the software makes all the calculations for AHP, FAHP, ANP, and FANP and displays the results on the screen. Then the user evaluates the results calculated by the software for selected or for whole methods and makes his/her decision. The user interface is shown in Fig. 8.

	A	B	C	D	E	
1	Influences	Initial Cost	Maintenai	Fuel Cons	Max Spee	Cru
2	Initial Cost					
3	Maintenance Cost	1				
4	Fuel Cons Cost	1			1	
5	Max Speed	1	1	1		
6	Cruise speed	1	1	1		
7	Maneuver Cap	1		1	1	
8	Heavy Sea State	1			1	
9	Repair for Shallow W	1	1			
10	Maintenance Easines	1	1			
11	Maintenance frequer	1	1			
12	Shallow Water Usage	1				
13	Safety	1				
14	Jet Drive	1	1	1	1	
15	Surface Drive	1	1	1	1	
16	Stern Drive	1	1	1	1	

Figure 7 DESTEC 1.0 data input Excel sheet (Influances)

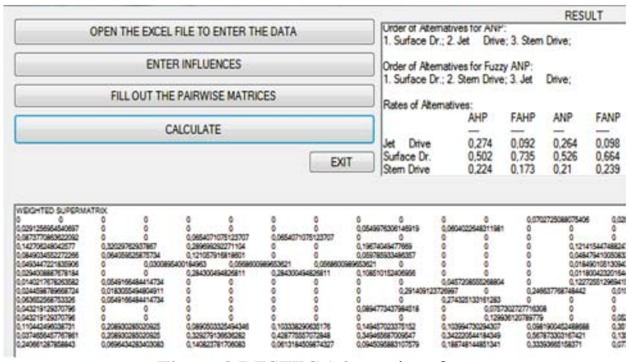

Figure 8 DESTEC 1.0 user interface

4 Proposed decision support model for propulsion system selection and an application

Although bay watch boats vary in dimension, the baywatch boat considered in this study is an IBB that will have the dimensions: 20÷25 m length, 4÷5 m width and 25÷35 tones displacement with maximum speed about 50 kts. The main design reason for the boat is to intervene in the emergency situations in the seaboard region. One of the important characteristics that will affect the whole system performance of the interceptor boat is the propulsion system. The proposed DSM is designed for determination of the appropriate propulsion system for an IBB. In the study, criteria and alternatives are determined by questionnaire technique applied to specialists, possible users working in marine sector and specialists working in shipyards in Tuzla region in Istanbul, which may be called the shipyard centre for Turkey.

Criteria and sub-criteria determined via questionnaire and deep discussions with the specialists in Turkish maritime sector (especially with the ones working in the Tuzla shipyard area) and also making use of previous studies.

Criteria and sub-criteria of the DSM are illustrated in Figs. 9 and 10. Here, the criterion "cost" has its sub-criteria "initial cost" (cost for first provision or purchasing cost), "maintenance cost" (cost for eliminating breakdowns and scheduled maintenance) and "fuel consumption" cost. The "performance" criterion has the sub-criteria of "maximum speed" and "cruising speed" which is the economic speed of the boat. "Manoeuvre capability" is how boat can manoeuvre mostly at maximum speed, since according to the aim of use İBBs are mostly used at top speeds in emergency situations, and at probably heavy sea states. The criterion "Heavy Sea State" is about the endurance of the boat to high seas from the view of propulsion system. The "maintenance" criterion has sub-criteria "Repair for Shallow Water Breakdowns" which evaluates the difficulty of repairing the propulsion system when the boat hits the ground in shallow waters. "Maintenance Easiness" is for evaluating generally how easy to repair that propulsion system in breakdowns or to carry out the scheduled maintenance. "Maintenance Frequency" is asking about the propulsion systems scheduled maintenance quantity. The "Shallow Water Usage" criterion is about in how much shallow water that propulsion system can be used. Lastly "Safety" is about the safety of the personnel using the boat or of the people as the boat will occasionally be used in coast area. Fig. 9 illustrates the hierarchy for AHP and FAHP, and Fig. 10 illustrates the network for ANP and FANP.

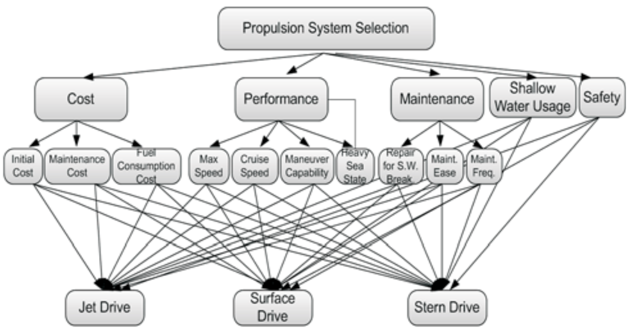

Figure 9 Hierarchy for AHP and FAHP

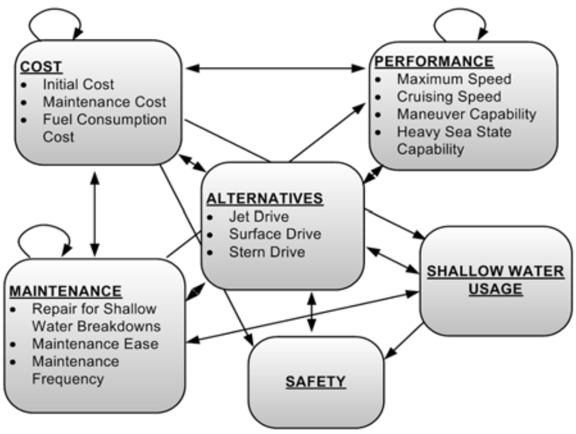

Figure 10 Network for ANP and FANP

The influences between criteria are illustrated in Tab. 3.

The alternatives for this problem are determined as Jet Drives, Surface Drives and Stern Drives. These drives are among the most widely used and generally accepted ones for small and fast boats like IBBs. There are other propulsion systems such as "inboard drives" or "conventional drives" but they do not fit the speed constraint for IBB.

The jet drives (water jets) have a propeller inside the engine which accelerates the water that gets in the hole under the boat and pushes it from the stern with high pressure and this power moves the boat. The surface drives looks more like conventional drives, the engine is inside, and the propeller is outside. Here the main difference is that the propeller is at the stern of the boat instead of under the boat in the water. The shaft is not static and protrudes approximately 5 ft. far from the transom. It can be moved to the right-left (as a rudder) and up-down. The propeller in this system is not fully inside the water [18].

Table 3 The Influence between Criteria

Influenced Criteria	Influencing Criteria
Initial Cost	Maintenance Cost, Fuel Consumption Cost, Max Speed, Cruise Speed, Maneuver Cap., Heavy Sea State, Repair for Shallow Water Breakdowns, Maintenance Ease, Maintenance Frequency, Shallow Water Usage, Safety, Jet Drive, Surface Drive, Stern Drive.
Maintenance Cost	Max Speed, Cruise Speed, Repair for Shallow Water Breakdowns, Maintenance Easiness, Maintenance, Frequency, Jet Drive, Surface Drive, Stern Drive.
Fuel Consumption Cost	Max Speed, Cruise Speed, Maneuver Cap., Jet Drive, Surface Drive, Stern Drive.
Max Speed	Fuel Consumption Cost, Maneuver Cap., Heavy Sea State, Jet Drive, Surface Drive, Stern Drive.
Cruise Speed	Fuel Consumption Cost, Maneuver Cap., Heavy Sea State, Jet Drive, Surface Drive, Stern Drive.
Maneuver Capacity	Max Speed, Cruise Speed, Heavy Sea State, Jet Drive, Surface Drive, Stern Drive.
Heavy Sea State	Jet Drive, Surface Drive, Stern Drive.
Repair for Shallow Water Breakdowns	Maintenance Cost, Maintenance Ease, Shallow Water Usage, Jet Drive, Surface Drive, Stern Drive.
Maintenance Ease	Maintenance Cost, Repair for Shallow Water Breakdowns, Maintenance Frequency, Jet Drive, Surface Drive, Stern Drive.
Maintenance Frequency	Max Speed, Cruise Speed, Maneuver Cap., Heavy Sea State, Maintenance Easiness, Shallow Water Usage, Jet Drive, Surface Drive, Stern Drive.
Shallow Water Usage	Repair for Shallow Water Breakdowns, Maintenance Ease, Safety, Jet Drive, Surface Drive, Stern Drive.
Safety	Jet Drive, Surface Drive, Stern Drive.
Jet Drive	Initial Cost, Maintenance Cost, Fuel Consumption Cost, Max Speed, Cruise Speed, Maneuver Cap., Heavy Sea State, Repair for Shallow Water Breakdowns, Maintenance Ease, Maintenance Frequency, Shallow Water Usage, Safety.
Surface Drive	Initial Cost, Maintenance Cost, Fuel Consumption Cost, Max Speed, Cruise Speed, Maneuver Cap., Heavy Sea State, Repair for Shallow Water Breakdowns, Maintenance Ease, Maintenance Frequency, Shallow Water Usage, Safety.
Stern Drive	Initial Cost, Maintenance Cost, Fuel Consumption Cost, Max Speed, Cruise Speed, Maneuver Cap., Heavy Sea State, Repair for Shallow Water Breakdowns, Maintenance Ease, Maintenance Frequency, Shallow Water Usage, Safety.

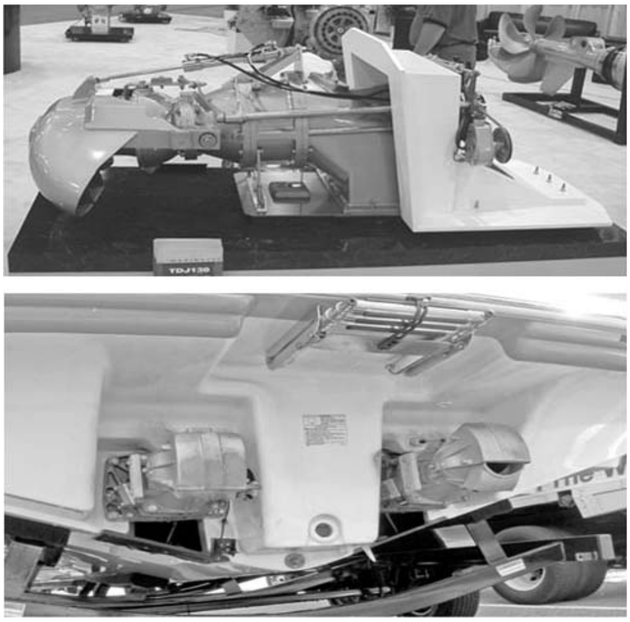

Figure 11 Jet Drives [18]

Figure 12 Jet Drives [18]

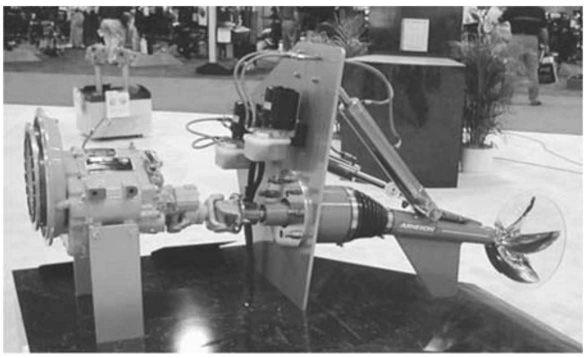

Figure 13 Surface Drive [18]

The upper half of it is out of the water. According to the sea conditions and speed of the boat the up-down movement provides better trim and stability. It also lessens the drag caused by the propeller so saves from power and fuel or makes more power. The stern drives look like the surface drives. But here the propeller is inside the water and has a Z type shaft instead of a straight shaft. The propellers can be moved right-left as a rudder also. At all these systems the size and shape of the propellers differ according to the design [18]. These drives are seen in Figs. 11÷13.

5
Results and conclusions

This paper presents a DSM for the propulsion system selection for an IBB which is aimed to be used for interfering in emergency situations in the seaboard shallow water regions. The application is performed with an originally developed fuzzy based hybrid DSS, DESTEC1.0, which enables the decision maker to use AHP, FAHP, ANP and FAHP methods all at once at the same time. The criteria for the DDM and the weights are determined via questionnaire technique applied to specialist, possible users working in marine sector and specialist working in shipyards. The questionnaires filled out by the experts are synthesized by geometric average and entered to the DSS. The results of the DSS pointed out that "Surface Drive" is the appropriate propulsion system for the IBB considered. The whole results of the application are illustrated in Tab. 4 (also see Fig. 8).

Table 4 Results

	AHP	FAHP	ANP	FANP
Jet Drive	0,274	0,092	0,264	0,097
Surface Drive	0,502	0,735	0,526	0,664
Stern Drive	0,224	0,173	0,210	0,239

The results also illustrate that, although Surface Drive alternative is costly, due to its performance and maintenance secular terms, it appears as the appropriate propulsion system for the IBB considered in this study.

Further researches can be made by extending the proposed DSM with much more technical criteria using other fuzzy MCDM such as TOPSIS, fuzzy ELECTRE or PROMTHEE. And also via presented DSS; DESTEC 1.0, more complex MCDM problems can be taken into consideration and solved, such as relatively new and rapidly drawing attention technologies used in manufacturing systems like abrasive water jets [19] and their usages [20].

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