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A DECISION-MAKING MODEL PROPOSAL (AAV) FOR SELECTION OF AMPHIBIOUS ATTACK VEHICLES FOR LANDING PLATFORM DOCK (LPD) BY INTEGRATED MCDM METHODS

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ABSTRACT: Landing Platform Dock (LPD) designed to have the primary task functions of "Transferring of Forces" and "Amphibious Operations" has been fully equipped for those operations. Selecting the best vehicles for LPD used to fulfill the specified operations is a complex process. In this article, the ELECTRE method, which is one of Multi-Criteria Decision-Making (MCDM), has applied the selection of Amphibious Assault Vehicles (AAV) deployed in LPD. For this case study, firstly, information about AAVs is given, and the Analytical Hierarchy Process (AHP) used for the research and the ELECTRE method, which is the basis of the study are explained. Within the scope of the study, the criteria required for the model have been determined by a delegation in the field of amphibious operations in the Naval Forces, four different AAVs in the international defense industry markets have been examined by the same delegation. The criteria weights, which use for the application of the ELECTRE method, have been determined by AHP.

Key Words: *Multi-Criteria Decision-Making (MCDM)*, *Analytical Hierarchy Process (AHP), ELECTRE, Landing Platform Dock (LPD), Amphibious Assault Vehicles (AVV), Defense Industry*

Bütünleşik ÇKKV Metotları ile Çok Maksatlı Amfibi Hücum Gemisi için Zırhlı Amfibi Araçların (AAV) Seçimine İlişkin Bir Karar Verme Model Önerisi

ÖZ: Çok Maksatlı Amfibi Hücüm Gemileri (LPD) "Kuvvet Aktarımı" ve "Amfibi harekat" ana görev fonksiyonlarına sahip olacak şekilde tasarlanmış ve bu harekat fonksiyonları için gerekli bütün araçlarla donatılmış olmalıdır. Belirtilen görev fonksiyonlarını gerçekleştirmek için hangi tip aracın en uygun olduğuna karar verme ve seçim süreci ise zor ve birden fazla kriterin bir arada değerlendirilmesini gerektiren karmaşık bir süreçtir. Bu makalede, Çok Kriterli Karar Verme (ÇKKV) yöntemlerinden AHS veELECTRE yaklaşımları birlikte kullanılmıştır. Çalışmada öncelikle Analitik Hiyerarşi Süreci (AHP) ve çalışmanın temeli olan ELECTRE yöntemi açıklanmış ve AAV'ler hakkında bilgi verilmiştir. Çalışma kapsamında, model için gerekli kriterler amfibi harekat alanında tecrübeli bir kurul tarafından belirlenmiş, uluslararası savunma sanayi pazarlarında dört farklı AAV aynı kurul tarafından incelenmiştir. ELECTRE yönteminin uygulanmasında kullanılan ölçütler AHP tarafından belirlenmiştir. Daha sonra ELECTRE yöntemi ile LPD'de konuşlandırılabilecek Zırhlı Amfibi Araçlar (AAV) arasında bir sıralama yapılmış ve en uygun olan AAV seçilmiştir.

Anahtar Kelimeler: *Çok Kriterli Karar Verme (ÇKKV), Analitik Hiyerarşi Süreci (AHS), ELECTRE, Çok maksatlı amfibi hücum gemisi (LPD), Zırhlı Amfibi Araçları (AAV), Savunma Sanayi*

INTRODUCTION

The military developments of the 21st century have brought a new concept on the military campaign. After World War II and The Post-Cold War, the Probability of conventional war over the border of the countries has almost come to an end. Nowadays, conflicts occur in the beyond the border and far away from the homeland. In this war environment, the countries need to be able to transfer the necessary forces on the conflict zone via the fastest ways. The most accessible and comprehensive approach for the transfer of these forces is carried out by sea transportation. For this transportation, A variety of vessels which provide permissiveness at a certain level for operation and logistic issue without the support of their main base in the conflict zone are required. The Countries which conduct this type of operation in the World use aircraft carriers and the LPDs. Navy Forces needs this type of vessel, which can transport the forces that need for operation anywhere on time. Because of this requirement, the construction of LPD has started

LPD will be able to use in operational areas of the Black Sea, Mediterranean, and the Aegean Sea and also will be used in the Indian Ocean and the Atlantic Ocean. Besides, that LPD, which will have a full-fledged hospital with 34 beds, will be able to serve on a humanitarian operation such as disaster relief and peacekeeping support operations.

LPD, which is constructed to have the primary task functions of "Transferring of Forces" and "Amphibious Operations," has been assigned the necessary staff who shall be controlling those functionings. LPD has the abilities in terms of operational speed and agility, by carrying the amphibious vessels; Landing Craft Marine (LCM), Landing Craft Air Cushion (LCAC), Landing Craft Vehicle Personnel (LCVP) and Assault Amphibious Vehicles (AAVs) to the operation region. The LPD is equipped with the essential landing/take-off and distribution capabilities/capabilities for helicopters and rotational rotor aircraft that provide support for the air campaign in Amphibious Operations.

Selecting the best vehicle used to fulfill the specified skills is a complex process. There are a lot of questions asked about which type of aircraft, helicopters, and other air platforms will be deployed on board, and what type of AAVs will be MCDM can be used to determine which vehicles been on the International Defense Industry market is more appropriate.

In this study, The ELECTRE model, which is one of MCDM, has applied the selection of AAVs deployed in LPD. For this purpose, the AHP and the ELECTRE method, which is the basis of the study are explained. Within the scope of the study, the criteria required for the model have been determined by a delegation in the field of amphibious operations in the Naval Forces, Four different AAVs in the international defense industry market have been examined by the same delegation. Criteria’s weights, which use for the application of the ELECTRE method, have been determined by AHP. Four different AAV which is available on the market sequences with the ELECTRE method, the results have been discussed, and suggestions have been presented.

LITERATURE SURVEY

MCDM is used in many areas by decision-makers. The areas in which are using the MCDM can be defined as; Environmental management and natural resources, Business management, Energy management, Structural, construction, and transportation engineering, Logistics and supply chain management, Information technology, Financial management, Policy, social and education, Chemical and biochemical engineering, Agriculture and horticulture, Health, Other areas and non-specific applications(Govindan and Jepsen 2016)

Even though the defense industry does not entirely been defined to relate which category of MCDM, it can be evaluated in the selection of suppliers in the area of logistics and supply chain management.

The choice of AAV for LPD can be evaluated as the supplier selection problem in the defense industry. In the literature survey section, first summarizes the work done with the MCDM in the defense industry. Later, works that apply in the other sectors of MCDM was mentioned. Then it is investigated how the use of the ELECTRE method, which is planned to solve the problem of selection of AAV for LPD.

MCDM in Defense Industry

A study on the selection of weapon systems was conducted using the AHP to select the best light machine gun Alternative weapons considered to be procured were evaluated with the help of the prepared survey. Alternatives are listed using Super Decisions 1.6.0 (Gençer et al., 2009).

In work done with the selection of suppliers in the defense industry, an important system integrator company is listed by the TOPSIS method, which will work together in visual direction. Supply chain and MCDM methods are described under study. As a result, an application was made to combine the procurement process with the MCDM procedure. Within the scope of implementation, four suppliers selected on a total of 5 criteria were evaluated by four decision-makers, and the most suitable supplier for the firm was selected (Çelikol, 2017).

Within the scope of the master thesis study related to the best pistol selection problem, the experience of the expert staff in the field was used to determine the criterion and the fuzzy AHP in which the importance weights were expressed as fuzzy numbers. In addition to AHP resolution, two different methods have been used to deal with the problem in the fuzzy logic environment. These are compared with the fuzzy suitability index of the pistols by the direct weighting method and compared with the fuzzy suitability index of the pistols using the relative measures obtained by AHP. The same sequence was handled in all methods applied (Tekeş, 2002).

Submarine types required by the submarine fleet were assessed relative to the project selection methods using the AHP method. Criteria for selection of submarine vessels have been identified and evaluated by expert personnel. Super Decision and Expert Choice programs were used for the evaluation. Values are the same in both programs. At the end of the study, the essential criterion for submarine selection was identified. Recommended providing the most suitable submarine according to the criteria set (Palaz and Kovancı, 2008).

Technology transfer techniques that were used in the defense industry were listed by the AHP method. Technology transfer techniques have been discussed in detail, and it has been researched that hangs are used in defense. Criteria which were used for AHP were determined on the basis of interviews with officials responsible for technology management of defense companies in Ankara, officials of public institutions related to researchers and defense industry, and the most suitable technology transfer method was provided by comparing with AHP method (Balcı, 2013).

The problem of investment project selection for an enterprise operating in the air defense industry from the lower branches of the defense industry is discussed. Criteria and alternatives have been identified and evaluated by 20 investment specialists. The obtained data were weighted using the AHP method. The obtained weights were applied to the VIKOR method to obtain a ranking (Uçakcıoğlu and Eren, 2017)

The evaluation of the navy tactical missile system was carried out with the Fuzzy AHP technique. Criteria for all options were evaluated by experts using the fuzzy method. The practical grade membership function grade is calculated to find out the performance scores. The criterion value is calculated according to missile performances. With the fuzzy AHP method, the total weights of the options were obtained. A ranking was made between the options (Cheng, 1997)

The AHP method was addressed in the problem of the selection of attack helicopters. The criteria and alternatives are determined by experts, and the values obtained are listed by AHP (Cheng et al., 1999).

Use of MCDM in Different Sectors

A problem with the choice of facility location selection Isparta / Turkey AHP has also been used to determine the place where animal husbandry. Within the scope of the study, seven districts of Isparta province were evaluated according to five different criteria (location, environmental factors, labor force, investment costs, laws). Environmental factors were chosen as the most important criteria affecting the place of establishment in the study conducted with AHP. The result is a ranking between the counties (Ömürbek, 2013).

It has been evaluated that a solution can be found in the field of logistics with the ELECTRE method, which is one of the multi-criteria decision-making methods. Cargo companies located in the city of Malatya were surveyed, and the weight of the charters determined by using the ELECTRE method was analyzed. The location of the cargo company's newly opened store was tried to be determined through the analyzes. It was thought that the analysis would give the firm an idea of where to find a place for the new store (Yücel and Ulutaş , 2009).

Fuzzy PROMETHEE technique is used in MCDM study with automobile selection and price, fuel, performance, and safety criteria are applied for seven different types of automobiles in the same class. It is very difficult and complex that the classic PROMETHEE method can work with linguistic values. Hence the linguistic values were used in the PROMETHEE method after the fuzzy. The obtained data were evaluated by Decision Lab software and PROMETHEE I and II. It has been seen that the results obtained in the study are consistent and appropriate (Ballı, 2007).

The problem of choosing a procurement planning engineer for an operator operating in the food industry related to the selection problem of personnel in operation is addressed. AHP, which is an effective method for evaluating qualitative and quantitative variables, has been used in the selection of personnel by defining the qualitative and quantitative criteria which are important for the operation. In the evaluation of the criteria and alternatives, the priority values of the main criterion were obtained with the Extended Analysis Method using linguistic variables and fuzzy numbers. When the designed system is examined, the results show that this method provides a visible solution to decision-making by providing a numerical solution to staff selection (Özgörmüş, 2005).

Fuzzy MCDM was used to select the main battle tank. Experts' views are explained in terms of trapezoidal (or triangular) fuzzy numbers, and the hierarchical structure of the decision problem is established. Fuzzy DELPHI method is used to set the blurriness ratio to reach the consensus of all experts. Subsequently, the fuzzy decision matrix is multiplied by the corresponding fuzzy feature weights to obtain the total number of fuzzy numbers. Herrera & Martinez's method, which is a synthetic method, was chosen as the best main battle tanks (Cheng and Lin, 2002).

Studies Conducted by Applying the Method ELECTRE

A business operating, which is a problem of supplier selection in the machinery sector, was dealt with Analytical Network Process (ANP), and ELECTRE methods that are multi-criteria decision-making techniques for supplier selection were applied in an integrated manner to solve the problem. The five main criteria and 15 sub-criteria, which are related to the probing, are weighted by the ANP method. Subsequently, the ANP method was used in the ELECTRE matrix, and 12 suppliers were evaluated using the ELECTRE method to determine the best supplier for the business (Çakın and Özdemir, 2013)

The detection problem of the echocardiography device, which was considered to be taken to the Cardiology Department of the hospitals was discussed. Criteria were determined by three physicians from the field of cardiology, and the criteria to be identified were evaluated using the AHP method. The obtained data and alternatives were ranked by the TOPSIS method to provide optimal options. (Erenet al., 2017).

The TOPSIS and fuzzy AHP methods have been used together to determine the most appropriate binding shape that can be used by the gas companies located in the Yarımca openings in the east of the Marmara Sea. Twelve different multi-point tanker-float linkage systems were considered, and while fuzzy AHP was used to reveal the weights of the traits to select the best among these options, fuzzy TOPSIS methods were used during the ordering and selection of the linkage systems (Menteş, 2010)

In the 2012-2013 season in Turkey, the performance of 6 football players who scored 15 goals or more in the soccer league. The weights of the criteria were determined by the Analytic Hierarchy Process (AHS) method. The obtained criteria weights were first ranked by evaluating the performances of the soccer players in the method of TOPSIS in the method of Technique for Order Preference by Similarity to an Ideal Solution. The obtained criteria weights were first ranked by evaluating the performances of the soccer players in the method of TOPSIS after ranked by VIKOR (Karaatlı et al., 2014).

Criteria for selecting laptop computers to be used in enterprises are weighted to the Fuzzy Analytical Hierarchy Process (BAHP) method because the classical AHP method is insufficient to handle the subjective judgments of decision-makers. The ELECTRE method was used for the selection of the essential products via the obtained data. an approach based on the combination of the methods of ELECTRE and FAHP was presented (Ertuğrul and Karakaşoğlu, 2010)

It is aimed to select the most suitable supplier considering more than one qualitative and quantitative criteria ELECTRE and AHP techniques were used to evaluate. ELECTRE, which is multi-criteria decision-making techniques, was presented as a technique to evaluate alternatives according to the sorting principle, and the AHP was used to determine the weight of the selection criteria (Soner and Önüt, 2006).

MCDM tested the quality assessment of websites for advertising tourist destinations. For this problem, experienced personnel has demonstrated a hierarchical structure of the criteria. ELECTRE-III-H was thought to contribute to the solution of the problem, and the accuracy of the sequencing results was checked in different cases. Robustness analysis yielded almost accurate results in rankings for all cases. (Del Vasto-Terrientes et al., 2015).

In the study exploring the areas in which the ELECTRE method was used, the fields were collected in 13 categories. Categories were determined as Natural resources and environmental management (Water management.- Waste management- Land management, geology, and cartography- Forestry, natural reserves, and ecotourism- Other papers on natural resources and environmental management). Business management (Performance and benchmarking.- Human resources. - Investment decisions.- Other business management applications.). Energy management (Large scale energy management.). HVAC systems and small scale energy management (Design, mechanical engineering, and manufacturing system). Structural, construction, and transportation engineering. Logistics and supply chain management (Facility layout and location- Supplier selection.- Other logistics and supply chain management applications.). Information technology (Software evaluation- Network selection - E-commerce and m-commerce - Other information technology applications). Financial management (Portfolio and investment management- Other financial management applications). Policy, social, and education). Chemical and biochemical engineering. Agriculture and horticulture. Health, safety, and medicine various. Other areas and non-specific applications (Govindan et al., 2016).

For the construction projects, the ELECTRE method was used for the selection of subcontractors. The problem is focused on the result, and where there is no knowledge of relative importance, decision-makers were offered a very specific set of decision models. The model considered consists of three steps. Firstly, the individual ranking was obtained by the method of ELECTRE II. In the second stage, a matrix of alternatives to a wide range of decision-makers has been established. Finally, individual preferences were collected were applied by the ELECTRE IV method, and final collective evaluation was performed (Alencar et al., 2010).

In the study, an approach to the mutual discussion of messages to e-services has been worked on to help consumers reach a reasonable composite e-service solution. A variety of information on an e-service composition has been given and worked with a material tender and e-service process for property management in Taiwan. For each e-service component's step, e-service formalization, an e-service program model and the ELECTRE method, were used to determine the optimal selection order of e-services. Then, the e-service selected for each step was created with a message evaluation process. As a result, consumers are offered a reasonable composite e-service solution (Ke and Chen, 2012).

The intuitionistic fuzzy ELECTRE method was used to solve the plant location problem. The expressions of alternatives for each criterion and the weights of each criterion which are treated as linguistic terms characterized by triangular heuristic fuzzy clusters. As a result, the ranking for the selection of decision-makers were made (Cheng and Lin, 2002,)

Studies conducted with MDCM were examined. Different techniques were used to guide decision-makers in different sectors. The studies were generally formed as a combination of two methods. Firstly, the criteria and values determined by the experts are weighted by the AHP method. Then, according to another method chosen by the author, alternatives are listed. The works were improved by using the fuzzy technique. It was determined that the ELECTRE method was not used in defense industry as far as the author knows. Therefore, it was decided to use the ELECTRE method for the choice of AAV for LPD.

MCDM

MCDM is the most commonly used method of decision-making. It is the branch of a general Operational Research (OR) model that seeks solutions to decision problems according to some decision criteria. This widely used decision-making model is defined as MCDM.

AHP Method

Multi-dimensional and complex problems are be solved effectively by the AHP. AHP solve MCDMs with different and contradictious criteria via carrying out pairwise comparison matrices to decompose. The AHP has three main pillars of the decision-making process; introducing the model, comparison of criteria and/or alternatives, evaluating priority among alternatives (Jagadish and Ray, 2015).

Step 1: Introducing the hierarchical system.

A decision problem was identified as a hierarchical system. The objective of AHP is to achieve a hierarchical system by branching decision criteria and alternatives. (Albayrak and Erensal, 2004; Liu et al., 2012)

Step 2: Perform the pairwise comparisons.

In this step, comparison matrices are found out, and pairwise comparisons are evaluating. The determined decision criteria were compared with each other by making use of the corresponding basic level scale comparison. Table 1 below presents the comparison scale used by AHP (Dağdeviren, 2009).

Table 1. The Basic Level Scale For Pairwise Comparison

Intensity of importance	Explanation
1	Two activities or criteria contribute equally to the objective
3	Experience and judgment slightly favor one over another
5	Experience and judgment strongly favor one over another
7	An activity or criteria is strongly favored and its dominance is demonstrated in practice
9	Importance of one over another affirmed on the highest possible order
2,4,6,8	When compromise is needed

A square and reciprocal matrix can be identified via this pairwise comparison. A square and reciprocal matrix, see Eq. (1). The result of the pairwise comparison on n criteria can be summed up in an $(n * n)$ assessment matrix.

$$A = \left(a_{ij}\right)_{nxm} = \begin{bmatrix} a_{11}\, a_{12} \cdots a_{1m} \\ a_{21}\, a_{22} \cdots a_{2m} \\ \cdot \quad \cdot \quad \cdots \quad \cdot \\ \cdot \quad \cdot \quad \cdots \quad \cdot \\ a_{n1}\, a_{n2} \cdots a_{nm} \end{bmatrix} \qquad 1)$$

Step 3: Determining the relative importance of weights.

In the last step, all matrix obtained is normalized and apply computations to examination consistency. Via normalization, As a result of the calculations, the order of normalized weight vectors and criteria is determined. The random index is given in Table 2, and the maximum acceptable consistency ratio (CR) was determined as (0.1). CR is the ratio of the consistency index (CI) and the random index (RI). The CI and CR are obtained by using the following equations (Rouyendegh, 2014).

$$CI = \frac{\gamma_{max} - n}{n-1} \tag{2}$$

$$CR = \frac{CI}{IR} \tag{3}$$

Table 2. Random Index

n	1	2	3	4	5	6	7	8
R	0,0	0,0	0,5	0,9	1,1	1,2	1,3	1,4

3.2. ELECTRE Method

The ELECTRE method is a crucial MCDM method based on the comparison of the degree of dual significance between different decision options for each rating factor. (Rouyendegh and Erol, 2012). The procedure to be followed during the application of the ELECTRE method is set out below.

Step 1: Determination of Decision Matrix

Within the scope of the applied method, we set the criteria (n) in the columns of the relevant matrix and show the alternatives (m) from the lines. This generated matrix will give the standard matrix for the basis of the application.

$$A_{ij} = \begin{bmatrix} r_{11}\, r_{12} \cdots r_{1m} \\ r_{21}\, r_{22} \cdots r_{2m} \\ \cdot \quad \cdot \quad \cdots \quad \cdot \\ \cdot \quad \cdot \quad \cdots \quad \cdot \\ r_{n1}\, r_{n2} \cdots r_{nm} \end{bmatrix} \tag{4}$$

Step 2: Creating a normalized decision matrix as a result of operations

By using the formula shown below, a normalized decision matrix is obtained by normalizing the decision matrix.

$$x_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^{M} r_{ij}^2}} \qquad i = 1,2, \dots \dots, mj = 1,2, \dots \dots, n \tag{5}$$

The mathematical formula for the cost criteria other than the gain obtained is formed below.

$$x_{ij} = \frac{\frac{1}{r_{ij}}}{\sqrt{\sum_{i=1}^{M} \left(\frac{1}{r_{ij}}\right)^2}} i = 1,2, \dots \dots, mj = 1,2, \dots \dots, n \tag{6}$$

Within the scope of mathematical solutions, normalized decision matrix (X) was obtained;

$$X_{ij} = \begin{bmatrix} x_{11}\, x_{12} \cdots x_{1m} \\ x_{21}\, x_{22} \cdots x_{2m} \\ \cdot \quad \cdot \quad \cdots \quad \cdot \\ \cdot \quad \cdot \quad \cdots \quad \cdot \\ x_{n1}\, x_{n2} \cdots x_{nm} \end{bmatrix} \tag{7}$$

Step 3: Detection of weighted normalized decision matrix

The binary comparison matrix obtained by the AHP method as a result of the previous calculations will be multiplied by the normalized matrix. The result is a weighted normalized matrix.

$$v_{ij} = w_j . x_{ij} \tag{8}$$

As a result of calculations, the matrix W is a diagonal matrix which values of its main diameter is W and rest values are zero.

$$W = \begin{bmatrix} w_1 & 0 \dots . & 0 \\ 0 & w_2 \dots . & 0 \\ 0 & \dots \dots & w_n \end{bmatrix} \tag{9}$$

Step 4: Determine the concordance and discordance sets

Blocks obtained from the net weighted normalized matrix are evaluated for each pair, and the outputs obtained are tested as follows. If the alternative considered is more beneficial or equal in terms of a benefit than the other elements of the couple, the Concordance set is obtained and defined by C

$$C(p,q) = \{j, v_{pj} \geq v_{qj}\}, (a_1, a_2 = 1,2, \dots, m, \wedge\, a_1 \neq a_2) \tag{10}$$

the evaluated alternative is less useful than the other elements of the pair for the identified criteria. Discordance set is obtained and defined by D

$$D(p,q) = \{j, v_{pj} < v_{qj}\}, (a_1, a_2 = 1,2, \dots, m, \wedge\, a_1 \neq a_2) \tag{11}$$

Step 5: Calculate the concordance matrix

Concordance matrix is the matrix generated by adding the values of weights of Concordance set elements.

$$C_{pq} = E_j * W_j \tag{12}$$

Step 6: Calculate the discordance matrix

Discordance matrix is prepared by dividing discordance set members' values to the total value of the whole set.

$$D_{pq} = \frac{\sum_{j^0} |v_{pj^0} - v_{qj^0}|}{\sum_j |v_{pj} - v_{qj}|} \tag{13}$$

Step 7: To reveal the calculation of the advantages obtained

As a result of all the calculations obtained, concordance averages and discordance values are considered. Any Cpq value greater than or equal to the C average in the resulting Concordance matrix is specified as Yes. Any value less than or equal to the average D in the conflict matrix is specified as No.

Step 8: As a result of the determination of the net compliance and non-compliance matrix

In order to obtain a ranking among the alternatives put forward, it is necessary to determine the net conformity and discrepancy values. As a result of the sequence obtained, the sequences C and D may be the same, in which case more than one of the most useful options may be obtained. It is necessary to present the result ranking according to the ranking obtained.

$$C_p = \sum_{\substack{k=1 \\ k \neq p}}^{m} C_{pk} - \sum_{\substack{k=1 \\ k \neq p}}^{m} C_{kp} \tag{14}$$

$$D_p = \sum_{\substack{k=1 \\ k\neq p}}^{m} D_{pk} - \sum_{\substack{k=1 \\ k\neq p}}^{m} D_{kp} \qquad (15)$$

CASE STUDY

There are different criteria for the selection of AAVs which are in the market. These criteria play an important role in the selection of AAVs. Criteria used during the decision phase were chosen according to the usage concept of LPD by a team of personnel who have worked on amphibious operations in naval forces. These criteria are determined as cruise speed, land speed, endurance on water, Sea State Degree, weapon systems, and personnel capacities. Selected AAVs are given code names A, B, C, and D AAVs' are selected by the same delegation for evaluation of AAV in international markets. The selected criteria and selected AVVs are evaluated by the same committee, according to the evaluation table in Table 3.

As a first step in the solution of the problem, the evaluations made by the expert delegation are collected. In the second step, the criteria weights and decision matrix, which need the ELECTRE method is created with the help of the AHP method and the data collected from the delegation. In the third step, the problem is solved by the ELECTRE method with the decision matrix and criteria weights.

Step 1:.The criteria selected by the delegation and the evaluation table of the AAVs selected according to these criteria are presented in Table 3 and Table 4.

Table 3. Pairwise Comparisons of Criteria's Matrix

	CS	SL	EW	SD	WS	PC
Cruising Speed (CS)	1	1/3	1/2	1	1/5	1/5
Speed on Land (SL)	3	1	3	1	1/2	1/5
Endurance on Water (EW)	2	1/3	1	1/3	1/5	1/7
Sea State Degree (SD)	1	1	3	1	1/3	1/5
Weapon System (WS)	5	2	5	3	1	1/2
Personal Capacity (PC)	5	5	7	5	2	1

Table 4. Pairwise Comparison Matrix of the Cruising Speed (CS) Criterion

	A	B	C	D
A	1	1/3	1/2	1
B	3	1	3	1
C	2	1/3	1	1/3
D	1	1	3	1

Pairwise Comparison Matrixes of other criteria were obtained using the same method.

Step 2: The Decision Matrix and Weighting the Decision Matrix, which require for the ELECTRE method, is calculated by using the AHP method.

Once the matrix A is built, it is possible to derive from A the normalized pairwise comparison matrix A_{norm} by making equal to 1 the sum of the entries on each column, each entry a_{jk} of the matrix A_{norm} is computed as

$a'_{jk}=\frac{a_{jk}}{\sum_{i=1}^{m} a_{ik}}$,$A_{norm}$matrix is presented in Table 5 and Table 6.

Table 5. A_{norm}Matrix of Criteria

	CS	SL	EW	SD	WS	PC
Crousing Speed (CS)	0,06	0,03	0,03	0,09	0,05	0,09
Speed on Land (SL)	0,18	0,10	0,15	0,09	0,12	0,09
Endurance on Water (EW)	0,12	0,03	0,05	0,03	0,05	0,06
Sea State Degree (SD)	0,06	0,10	0,15	0,09	0,08	0,09
Weapon System (WS)	0,29	0,21	0,26	0,26	0,24	0,22
Personal Capacıty (PC)	0,29	0,52	0,36	0,44	0,47	0,45

Table 6. A_{norm}Matrix of AAV's Cruising Speed (CS)

	A	B	C	D
A	0,21	0,32	0,20	0,31
B	0,07	0,11	0,12	0,19
C	0,62	0,54	0,60	0,44
D	0,10	0,04	0,08	0,06

A_{norm} Matrix of other criteria was obtained using the same method.

After, the criteria weight vector w (that is an m-dimensional column vector) is built by averaging the entries on each row of A_{norm} .$w_i$is computed as $w_j = \frac{\sum_{l=1}^{m} a'_{jl}}{m}$. The weight matrix of the criteria calculating with the help of the above formula for all w_i is given Table 7, which is described as W matrix, and Table 8, which is described as Decision Matrix.

Table 7. Matrix of The Criteria's Weights

	CS	SL	EW	SD	WS	PC
w_i	0,06	0,12	0,06	0,10	0,25	0,42

Table 8. Decision Matrix

	CS	SL	EW	SD	WS	PC
A	0,26	0,23	0,35	0,28	0,28	0,57
B	0,12	0,23	0,35	0,45	0,45	0,06
C	0,55	0,12	0,11	0,16	0,16	0,13
D	0,07	0,42	0,19	0,11	0,11	0,24

Step 3: The problem is solved by the ELECTRE method. So the normalized matrix and weighted normalized matrix is calculated by using the following equation:

$$x_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{M} a_{ij}^2}}$$

Normalized Decision Matrix is obtained after all calculation with an equation which mentions above. Normalized Decision Matrix, which is described as X matrix, is shown in Table 9.

Table 9. Normalized Decision Matrix

	CS	SL	EW	SD	WS	PC
A	0,42	0,42	0,65	0,50	0,50	0,90
B	0,19	0,42	0,65	0,79	0,79	0,09
C	0,88	0,22	0,20	0,29	0,29	0,21
D	0,11	0,78	0,35	0,19	0,19	0,38

After the calculated normalized decision matrix. Weighting the Normalized Decision Matrix is calculated by an equation which is shown as $Y = X \times \mathrm{W}$. Weighting the Normalized Decision Matrix (Y matrix) is shown Table 10

Table 10. Weighting Normalized Decision Matrix

	CS	SL	EW	SD	WS	PC
A	0,0159	0,0601	0,0390	0,0736	0,1603	0,3902
B	0,0074	0,0601	0,0390	0,0736	0,1271	0,0368
C	0,0337	0,0323	0,0121	0,0300	0,0675	0,0788
D	0,0034	0,1120	0,0211	0,0211	0,0416	0,1518

After calculating the weighting normalized decision matrix, concordance and discordance sets are applied to describe the dominance query and the discordance interval set.

The concordance and discordance sets are given as;

$C_{12} = \{1,2,3,4,5,6\}$	$C_{21} = \{2,3,4\}$	$C_{31} = \{1\}$	$C_{41} = \{2\}$
$C_{13} = \{2,3,4,5,6\}$	$\boldsymbol{C_{23}} = \{2,3,4,5\}$	$C_{32} = \{1,6\}$	$C_{42} = \{1,2,6\}$
$C_{14} = \{1,3,4,5,6\}$	$C_{24} = \{1,3,4,5\}$	$C_{34} = \{1,4,5\}$	$C_{43} = \{2,3,6\}$
$D_{12} =$	$D_{21} = \{1,5,6\}$	$D_{31} = \{2,3,4,5,6\}$	$D_{41} = \{1,3,4,5,6\}$
$D_{13} = \{1\}$	$D_{23} = \{1,6\}$	$D_{32} = \{2,3,4,5\}$	$D_{42} = \{3,4,5\}$
$D_{14} = \{2\}$	$D_{24} = \{2,6\}$	$D_{34} = \{2,6\}$	$D_{43} = \{1,4,5\}$

Calculation of the concordance interval matrix: The concordance interval index (C_{ab}) between $A_a \wedge A_b$ can be obtained using the following equation and the concordance interval matrix can be formulated as

$$C_{a_1 a_2} = \sum_{\mathrm{j}} w_j$$

The concordance interval matrix is shown in Table 11.

Table 11. The Concordance Interval Matrix

0,0000	1,0000	0,9619	0,8557
0,3148	0,0000	0,5342	0,4281
0,0381	0,4658	0,0000	0,3678
0,1443	1,2194	0,6322	0,0000

Calculation of the discordance interval matrix: we consider the discordance index of d_{ab} . Then, using discordance interval index set, the concordance interval matrix can be formulated as

$$D_{ab} = \frac{max_{j \in D_{ab}} |v_{aj} - v_{bj}|}{max_{j \in J, m,n \in I} |v_{mj} - v_{nj}|}$$

The discordance interval matrix (D) is shown in Table 12.

Table 12. The Discordance Interval Matrix

0,0000	0,0000	0,0573	0,2175
1,0000	0,0000	0,7039	1,3449
1,0000	1,0000	0,0000	1,0000
1,0000	0,7436	0,3806	0,0000

Determine the concordance index matrix: The concordance index matrix for satisfaction measurement problem can be written as follows:

$\overline{c} = \sum_{a=1}^{m} \sum_{b}^{m} \frac{c(a,b)}{m(m-1)}$ $e(a,b) = 1 IF c(a,b) \geq \overline{c}$

$$e(a,b) = 1 IF c(a,b) < \overline{c}$$

$$\overline{c} = \frac{5.95}{4(4-2)} = 0,49$$

Concordance index matrix (E) is shown in Table 13

Table 13. The Concordance Index Matrix (E)

0	1	1	1
0	0	1	0
0	0	0	1
0	1	1	0

Determine the discordance index matrix: On the contrary, the preference of dissatisfaction can be measured by discordance index, the discordance index matrix (F) is given by:

$\overline{d} = \sum_{a=1}^{m} \sum_{b}^{m} \frac{d(a,b)}{m(m-1)}$ $f(a,b) = 1 IF d(a,b) \geq \overline{d}$

$f(a,b) = 0 IF d(a,b) < \overline{d}$

$\overline{d} = \frac{8,39}{4(4-2)} = 0,66$ and discordance index matrix (F) is shown in Table 14

Table 14. The discordance index matrix (F)

0	0	0	0
0	0	1	0
0	0	0	0
0	1	0	0

Calculation of Net Concordance and Net Discordance Values: Net concordance and net discordance values are presented in Table 15.

$$c_1 = (1,00 + 0,9619 + 0,8557) - (0,3148 + 0,0381 + 0,1443) = 2,320$$

$c_2 = (0,3148 + 0,5342 + 0,4281) - (1 + 0,4658 + 1,2194) = -1,4080$

$c_3 = (0,0381 + 0,4658 + 0,3678) - (0,9619 + 0,5342 + 0,6322) = -1,2565$

$c_4 = (0,1443 + 1,2194 + 0,6322) - (0,857 + 0,4281 + 0,3678) = 0,3442$

$d_1 = (0,0573 + 0,2175) - (1,00 + 1,00 + 1,00) = -2,7552$

$d_2 = (1,00 + 0,7039 + 1,3449) - (1,00 + 0,7436) = 1,3052$

$d_3 = (1,00 + 1,00 + 1,00) - (0,0573 + 0,7039 + 0,3806) = 1,8582$

$d_4 = (1{,}00 + 0{,}7436 + 0{,}3806) - (0{,}2175 + 1{,}3449 + 1{,}00) = -0{,}4383$

Table 15. Net Concordance and Net Discordance Values

	Net concordance Values	Net discordance Values	Ranking of Net Top Values	Ranking of Net Lowest Values
A	2,320	-2,7252	1	1
B	-1,4080	1,3052	4	3
C	-1,2565	1,8582	3	4
D	0,3442	-0,4383	2	2

Net concordance and net discordance values are also presented graphically in Figure-1 and Figure-2.

Figure-1

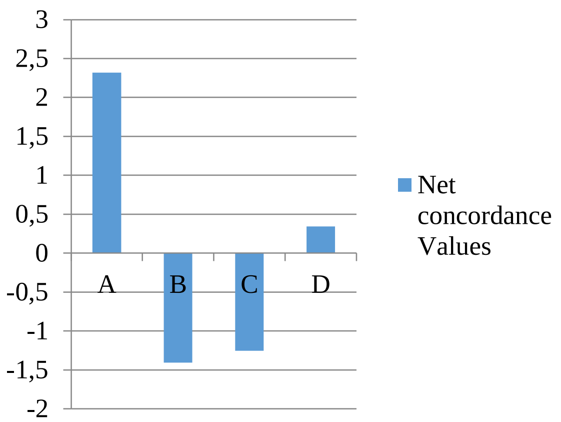
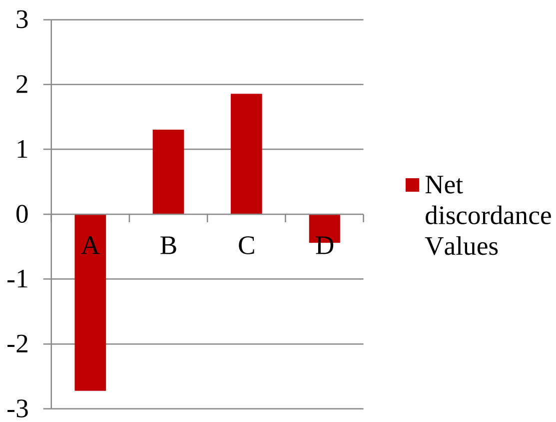


Figure-2



The AAVs are on the market compare in Table 15. Net Concordance and Net Discordance Values of the AVVs are found, and rank among the AAVs is found. According to this ranking, A is found to be the most appropriate AAV when considering net highest values and net lowest values.

CONCLUSIONS

LPD is considered to add a critical capacity that is at a strategic level to Navy Forces. Landing Platform Dock (LPD) constructed to have the primary task functions of "Transferring of Forces" and "Amphibious Operations" has been fully equipped for those operations. Selecting the best vehicles for LPD used to fulfill the specified operations is a complex process. In this article, the ELECTRE method, which is one of Multi-Criteria Decision-Making (MCDM) has applied the selection of Amphibious Assault Vehicles (AAV) deployed in LPD. For this reason, the selection of weapons and vehicles is an essential part of LPD projects.

In this study, the selection of AAVs, which are the vehicles deployed on this ship, are dealt with MCDM have been used to determine the most appropriate AAV with the usage concept of LPD and the concept of Naval Forces. Alternatives and criteria are evaluated in terms of their technical characteristics.

The criteria required for the model have been determined by a delegation in the field of amphibious operations in the Naval Forces, and four different AAVs in the international defense industry markets have been examined by the same commission. These criteria are determined as cruise speed, land speed, endurance on water, Sea State Degree, weapon systems, and personnel capacities. Selected AAVs are given code names A, B, C and D. Criteria’s weights and Alternative’s weights have been determined by the AHP method in terms of technical data obtained from open sources.

The ELECTRE method was applied to data, and the net concordance and net discordance values are determined by using the ELECTRE method. In the direction of the obtained data and the suitability of the alternatives are evaluated from the technical point of view.

As a result of the study, A is found to be the most suitable alternative when the net concordance and net discordance values are evaluated. The selection of the AAV is assessed to involve the front panel of the A alternative.

Different results will be obtained when criteria such as cost of AAVs and logistic sustainability (maintenance, repair, spare part etc.) are included in the work done. In addition, this study could be improved using a fuzzy logic framework with different multi-criteria decision-making methods to more effectively analyze cases having uncertainty.

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