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Evaluating Tactical Missile Systems by Using Fuzzy AHP and TOPSIS Technique

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Abstract- Evaluating tactical missile systems is a complex system of interacting elements. For example, a good missile system requests good missile performance and minimal cost; the performance and cost depend on improvement of science and technology and economic resources; technology depends on ideas and resources; ideas depend on politics for their acceptance and support; and so on. In such an intricate network of factors, first causes and then final effects cannot be identified easily. These factors directly depend on the expectations of the decision-maker, and on additional complex subfactors, etc. In the complex system, our minds have not yet evolved to the point where we can clearly see these ultimate relationships and readily resolve important issues. Evaluating tactical missile systems is a multi-criteria decision-making (MCDM) problem. This paper presents an evaluation model based on the analytic hierarchy process (AHP) and the technique for order performance by similarity to ideal solution (TOPSIS) in a fuzzy environment where the vagueness and subjectivity are handled with linguistic values parameterized by triangular fuzzy numbers. The AHP is used to analyze the structure of systems evaluating and to determine weights of the criteria, and fuzzy TOPSIS method is used to obtain final ranking.

Keywords- Triangular fuzzy numbers; Analytic Hierarchy Process (AHP); The technique for order performance by similarity to ideal solution (TOPSIS); Tactical missile systems.

1. Introduction

An ordinary English-language usage predating guided weapons, a missile is "any thrown object", such as objects thrown at players by rowdy spectators at a sporting event. In a modern military usage, a missile, or guided missile, is a self-propelled guided weapon system, as opposed to an unguided self-propelled munition, referred to as just a rocket. Missiles have four system components: targeting and/or guidance, flight system, engine, and warhead. All known existing missiles are designed to be propelled during powered flight by chemical reactions inside a rocket engine, jet engine, or other type of engine. Non-self-propelled airborne explosive devices are generally referred to as shells and usually have a shorter range than missiles.

Evaluating weapon systems plays an important role in the design of an effective defense system. In 1994, Cheng and Mon (C.H. Cheng & Mon, 1994) assessed weapon systems with AHP based on fuzzy scales. Chen (Chen, 1996) applied fuzzy set theory to evaluate weapon systems using fuzzy arithmetic operations. Cheng and Lin (C.H. Cheng & Lin, 2002) applied fuzzy decision theory to evaluate main battle tanks. Mon et al. (Mon, Cheng, & Lin, 1994) utilized fuzzy AHP based process on entropy weight to assess weapon systems. Cheng (C.H. Cheng, 1996, 1999) measured naval tactical missile systems and weapon systems with fuzzy AHP and ranking fuzzy numbers, respectively. Cheng et al. (C. H. Cheng, Yang, & Hwang, 1999) applied AHP to evaluate attack helicopters using linguistic variables.

Evaluating and selecting the optimal weapon system among many missile systems involves complex decisions. Such a problem can be solved using Multi Criteria Decision Making (MCDM) approach (Wang & Chang, 2007). MCDM approach has become a main area of research for dealing with complex decision problems. There are many studies that investigated the method about performance evaluation among the given missile systems. In the literature, there are few fuzzy based methods aimed at evaluating the relative performance considering multiple dimensions (Dagdeviren, Yavuz, & Kilinc, 2009). One of the most popular methods is analytic hierarchy process (AHP) (Göleç & Taşkın, 2007).

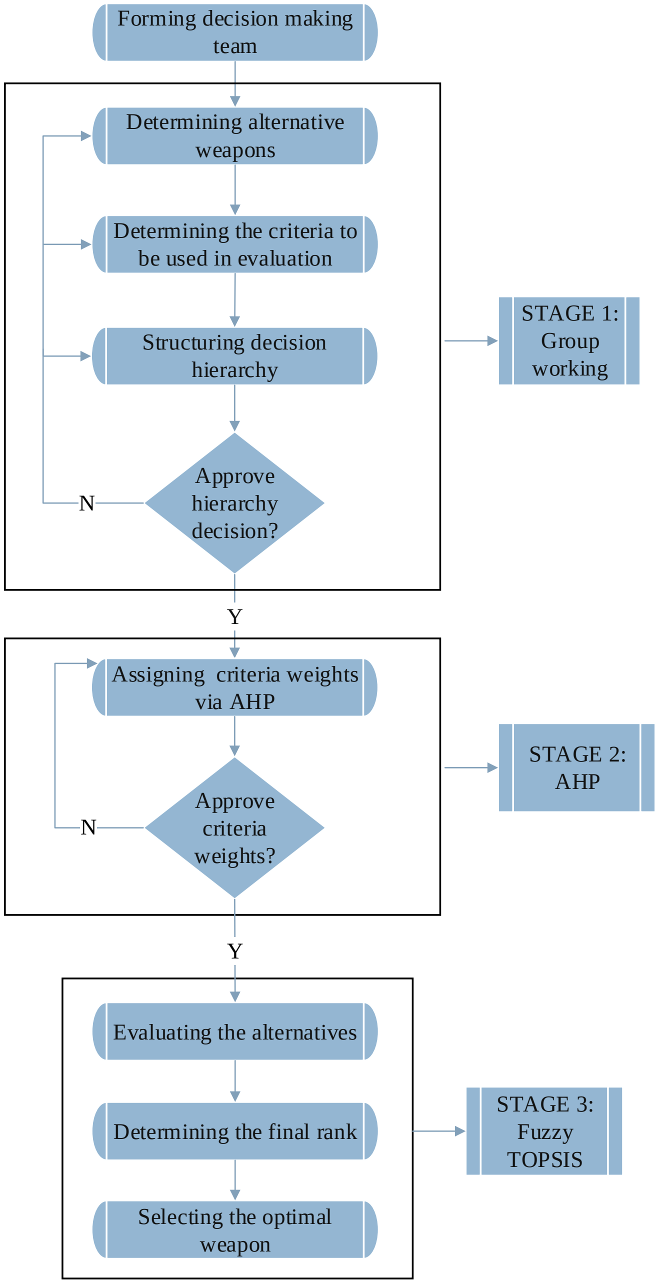

Fig. 1. Schematic diagram of the proposed model for weapon selection.

Evaluating weapon systems is both a MCDM problem where many criteria should be considered in decision-making, and a problem containing subjectivity, uncertainty and ambiguity in assessment process. The main purpose of this study is to utilize Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method under fuzzy environment to identify and rank the best missile systems among the tactical missile systems. The MCDM method choice decision should wait until the analyst and the decision-makers understand the problem, the feasible missile systems, different outcomes, conflicts between the criteria and level of the data uncertainty (Mergias, Moustakas, Papadopoulos, & Loizidou, 2007). Schematic diagram of the proposed model for weapon selection is provided in Fig. 1.

The paper is organized as follows: Section 2 briefly describes the proposed methods. In Section 3, proposed model for evaluating weapon systems is presented and the stages of the proposed approach are explained in detail. How the proposed model is used on a real world example is explained in Section 3. In Section 4, conclusions are discussed.

2. Methodology

2.1. Fuzzy sets and fuzzy numbers

Fuzzy set theory is a mathematical theory pioneered by Zadeh (Zadeh, 1965), which is designed to model the vagueness or imprecision of human cognitive processes. The key idea of fuzzy set theory is that an element has a degree of membership in a fuzzy set. A fuzzy set $\tilde{A}$ in a universe of discourse X is characterized by a membership function $\mu_{\tilde{A}}(x)$ which associates with each element x in X a real number in the interval $[0,1]$. The function value $\mu_{\tilde{A}}(x)$ is termed the grade of membership of x in $\tilde{A}$.

A triangular fuzzy number (TFN) $\tilde{a}$ can be defined by a triple(a_1, a_2, a_3). The membership function $\mu_{\tilde{a}}(x)$ is defined by

$$\mu_{\tilde{a}}(x) = \begin{cases} \frac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ \frac{a_3-x}{a_3-a_2}, & a_2 \le x \le a_3 \\ 0, & \text{otherwise.} \end{cases} \qquad (1)$$

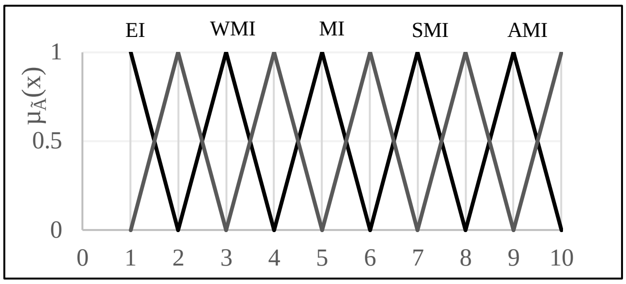

Fig. 2. Fuzzy membership function for linguistic values.

Fig. 2 shows the structure of triangular fuzzy numbers that are used in this paper. This research uses TFN for the pairwise comparisons and finds the fuzzy weights. The reason for using a TFN is that it is intuitively easy for the decision makers to use and calculate. In addition, modeling TFN has proven to be an effective way of formulating decision problems where the information available is subjective and imprecise.

2.2. Fuzzy analytic hierarchy process method

The AHP (Saaty, 1980) is a quantitative technique that structures a multi-attribute, multi-person and multi-period problem hierarchically so that solutions are facilitated. One of the main advantages of this method is the relative effectiveness with which it handles multiple criteria. It can effectively handle both qualitative and quantitative data (Kahraman, Cebeci, & Ruan, 2004; Boran et al., 2011). AHP method has the following properties:

- AHP is a method which is used to solve complex decision problems by determining the relative importance of a set of activities in a problem.
- AHP method decomposes a complex multi criteria decision problem into a series of interrelated decisions.
- AHP method is used in nearly crisp-information decision applications.
- AHP method creates and deals with a very unbalanced scale of judgment (Kaya & Kahraman, 2011).
- AHP method does not take into account the uncertainty associated with the process involved.

Even though the aim of AHP is to capture the expert's knowledge, the conventional AHP still cannot reflect the ambiguity in human thinking style. Therefore, fuzzy AHP, a fuzzy extension of AHP, was developed to solve the hierarchical fuzzy problems and many fuzzy AHP methods by various authors are proposed (Chamodrakas, Batis, & Martakos, 2010). This research uses triangular fuzzy numbers (TFNs) for the evaluation. The steps in Fuzzy AHP are presented as follows:

Step 1: Building the evaluation hierarchy systems for evaluating the best missile system among the given missile systems considering the various criteria involved. The selection of best missile system will be done based on building the hierarchical system.

Table 1. Linguistic values and fuzzy numbers.

Fuzzy number	Linguistic	Intensity of importance
9.0	Absolutely more important/improved (AMI)	(8.0, 9.0, 10.0)
8.0	Intermediate values	(7.0, 8.0, 9.0)
7.0	strongly more important/improved (SMI)	(6.0, 7.0, 8.0)
6.0	Intermediate values	(5.0, 6.0, 7.0)
5.0	More important/improved (MI)	(4.0, 5.0, 6.0)
4.0	Intermediate values	(3.0, 4.0, 5.0)
3.0	Weakly more important/improved (WMI)	(2.0, 3.0, 4.0)
2.0	Intermediate values	(1.0, 2.0, 3.0)
1.0	Equally important/improved (EI)	(1.0, 1.0, 2.0)
1	Just equal	(1, 1, 1)

Step 2: Determining the evaluation dimensions weights using triangular fuzzy numbers. Once the problem has been decomposed and the hierarchy is constructed, prioritization procedure starts in order to determine the relative importance of the criteria within each level. The pairwise judgment starts from the second level and finishes in the lowest level, missile systems. In each level, the criteria are compared pairwise according to their levels of influence and based on the specified criteria in the higher level

(Albayrak & Erensal, 2004). In AHP, multiple pairwise comparisons are based on a standardized comparison scale of nine levels (Table 1).

Let $C = \{Cj \mid j = 1, 2, \dots, n\}$ be the set of criteria. The result of the pairwise comparison on n criteria can be summarized in an $(n \times n)$ evaluation matrix A in which every element $a_{ij}\ (i, j = 1, 2, \dots, n)$ is the quotient of weights of the criteria.

Step 3: The weight for each criterion is determined. This is done by normalizing the matrix. The relative weights are given by the right eigenvector (w) corresponding to the largest eigenvalue λ_{max}, as $A \cdot w = \lambda_{max} w$. If the pairwise comparisons are completely consistent, the matrix A has rank 1 and $\lambda_{max} = n$. In this case, weights can be obtained by normalizing any of the rows or columns of A (Wang & Chang, 2007).

It should be noted that the quality of the output of the AHP is strictly related to the consistency of the pairwise comparison judgments. The consistency is defined by the relation between the entries of A: $a_{ij} \times a_{jk} = a_{ik}$. The consistency index (CI) is

$$CI = \frac{\lambda_{max} - n}{n - 1} \qquad (2)$$

The final consistency ratio (CR), usage of which let someone to conclude whether the evaluations are sufficiently consistent, is calculated as the ratio of the CI and the random index (RI), as indicated

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

If the value of Consistency Ratio is smaller than or equal to 10%, the inconsistency is acceptable. If the Consistency Ratio is greater than 10%, we need to revise the subjective judgment.

2.3. The fuzzy TOPSIS method

The primary concept of TOPSIS approach is that the most preferred missile system should not only have the shortest distance from the positive ideal solution (PIS), but also have the farthest distance from the negative ideal solution (NIS) (Dagdeviren et al., 2009). TOPSIS has a relative advantage that only limited subjective input is needed from decision makers and the ability of the method to identify the best missile system quickly. This study uses triangular fuzzy number for fuzzy TOPSIS. The reason for using a triangular fuzzy number is that it is intuitively easy for the decision-makers to use and calculate. In addition, modeling using triangular fuzzy numbers has proven to be an effective way for formulating decision problems where the information available is subjective and imprecise (Chang & Yeh, 2002; Kahraman, Beşkese, & Ruan, 2004). The steps involved in Fuzzy TOPSIS are presented as follows.

Step 1: Obtain the weighting of criteria from Fuzzy AHP. The result of Fuzzy AHP contains the weights of each criterion under consideration.

Step 2: Create Fuzzy evaluation matrix. The judgmental values from decision makers for each decision missile system corresponding to each criterion are tabulated with TFNs as entries.

Step 3: Normalize fuzzy decision matrix. The normalized fuzzy decision matrix is denoted by R whose elements are $[r_{ij}]_{m \times n}, i = 1;\ 2;\ 3;\ \dots m$, where m is the total number of missile systems. The fuzzy linguistic rating $\tilde{r}_{ij}$ preserves the property that the ranges of normalized triangular fuzzy numbers belong to $[0, 1]$. Thus, there is no need for normalization.

Step 4: Calculate the weighted normalized decision matrix by multiplying the normalized decision matrix by its associated weights. The weighted normalized value v_{ij} is calculated as

$$v_{ij} = r_{ij} \times w_i\,, \qquad i = 1, 2, \dots, m\ , \qquad j = 1, 2, \dots, n \qquad (4)$$

where w_i represents the weight of the ith criterion.

Step 5: Determine the fuzzy positive ideal and fuzzy negative ideal reference points. Fuzzy positive ideal solution (FPIS, A^*) and fuzzy negative ideal solutions (FNIS, A^-) are defined by the area compensation technique:

$$A^* = \{\tilde{v}_1^*, \dots, \tilde{v}_i^*\} = \left\{\left(\max_j v_{ij}, i \in I'\right), \left(\min_j v_{ij}, i \in I''\right)\right\}$$

$$A^- = \{\tilde{v}_1^-, \dots, \tilde{v}_i^-\} = \left\{\left(\min_j v_{ij}, i \in I'\right), \left(\max_j v_{ij}, i \in I''\right)\right\} \qquad (5)$$

where $v_{ij} = r_{ij} \times w_i$, I' is associated with benefit criteria and I'' is associated with cost criteria for $i = 1, \dots, m$ and $j = 1, \dots, n$.

Step 6: Calculate the distance of each missile system from A^* and A^- using the following equations:

$$D_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*) , \quad i = 1,2, \ldots , m,$$

$$D_i^- = \sum_{j=1}^{n} d\left(\tilde{v}_{ij}, \tilde{v}_j^-\right), \quad i = 1,2, \ldots , m, \qquad (6)$$

where $d(\tilde{a}, \tilde{b})$ is the distance between the two fuzzy numbers $\tilde{a}$ and $\tilde{b}$. It is defined as $d\left(\tilde{a}, \tilde{b}\right) = \sqrt{\frac{1}{3}(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2} \qquad (7)$

Step 7: The relative closeness to the ideal value is determined and missile systems are ranked accordingly. The relative closeness is given by

$$CC_i = \frac{D_i^-}{D_i^* + D_i^-} \qquad (8)$$

An interested reader can find more information on such methods in (Büyüközkan & Çifçi, 2012; Juniora, Osirob, & Carpinetti, 2014; Vinodh, Prasanna, & Hari Prakash, 2014).

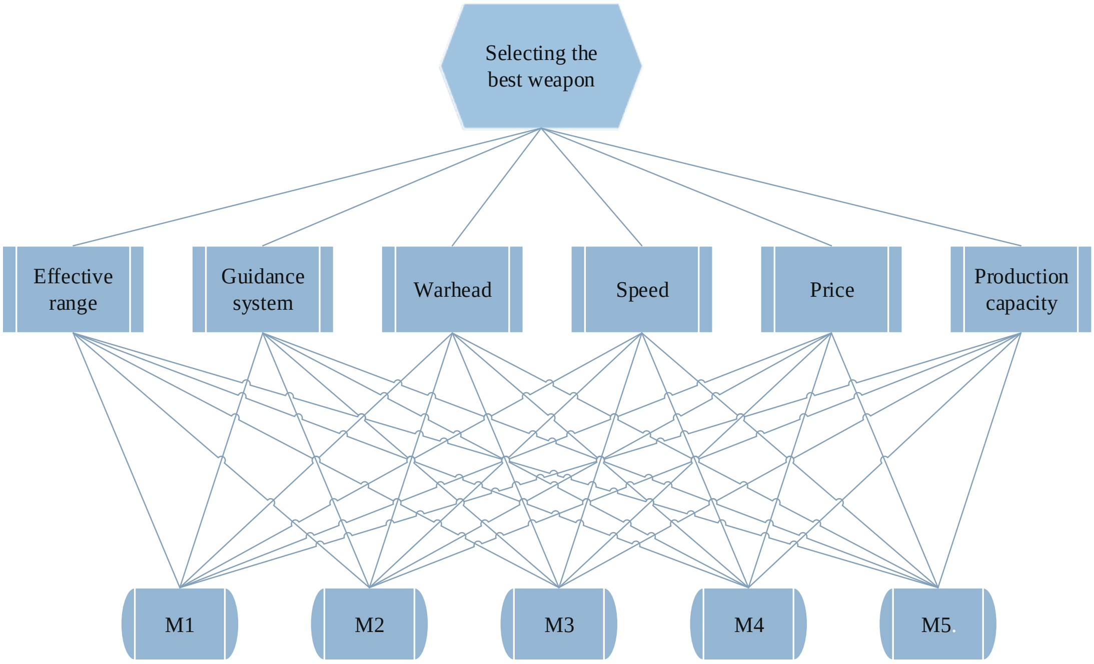

Fig. 3. The decision hierarchy of weapon selection.

3. Evaluating tactical missile systems

3.1. Criteria

Criteria to be considered in the evaluating tactical missile systems are determined by the expert team. Criteria and their definitions of importance are given in Table 3. This study involves the selection of best tactical missile using the Fuzzy AHP–TOPSIS technique. The proposed model composed of AHP and fuzzy TOPSIS methods, consists of three basic stages: (1) identify the criteria to be used in the model, (2) AHP computations, (3) evaluation of missile systems with fuzzy TOPSIS and determination of the final rank. In the first stage, missile system and the criteria which will be used in their evaluation are determined and the decision hierarchy is formed.

AHP model is structured such that the objective is in the first level, criteria are in the second level and missile systems are on the third level. In the last step of the first stage, the decision hierarchy is approved by decision-making team.

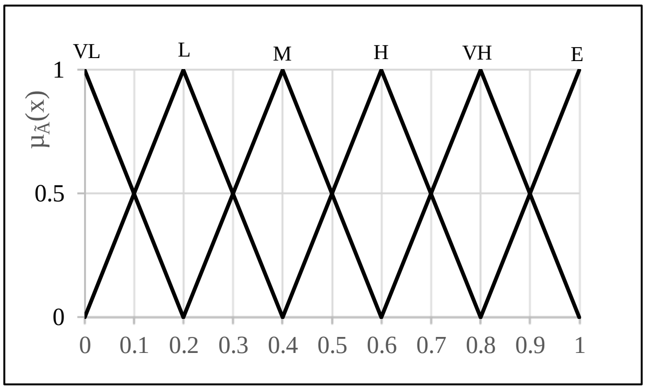

Fig. 4. Membership functions of linguistic values for criteria rating.

Table 2. Linguistic values and fuzzy numbers.

Linguistic	Fuzzy numbers
Very low (VL)	(0.0, 0.0, 0.2)
Low (L)	(0.0, 0.2, 0.4)
Medium (M)	(0.2, 0.4, 0.6)
High (H)	(0.4, 0.6, 0.8)
Very high (VH)	(0.6, 0.8, 1.0)
Excellent (E)	(0.8, 1.0, 1.0)

After the approval of decision hierarchy, criteria used in evaluating systems are assigned weights using AHP in the second stage. In this phase, pairwise comparison matrices are formed to determine the criteria weights. Five experts from decision- making team make individual evaluations using the scale provided in Table 1, to determine the values of the elements of pairwise comparison matrices. Geometric means of these values are found to obtain the pairwise comparison matrix on which there is a consensus (Table 4). For example,

$$\tilde{a}_{14} = \left((1 \times 3 \times 2 \times 1 \times 1)^{\frac{1}{5}}, (1 \times 4 \times 3 \times 2 \times 1)^{\frac{1}{5}}, (2 \times 5 \times 4 \times 3 \times 2)^{\frac{1}{5}}\right) \tag{9}$$

$$= (1.4, 1.8, 2.9).$$

The weights of the criteria are calculated based on this final comparison matrix. In the last step of this phase, calculated weights of the criteria are approved by decision making team.

Table 3. Weapon evaluation criteria and its definition.

	Criteria	Definition
C1	Effective range	Distance from the launcher that a missile fired from the launcher can reliably hit the target.
C2	Guidance systems	The missile's target accuracy is a critical factor for its effectiveness. This guidance system guides the missile by knowing the missile's current position and the position of the target, and then calculating a course between them. This job can also be performed somewhat crudely by a human operator who can see the target and the missile, and guides it using either cable or radio based remote-control, or by an automatic system that can simultaneously track the target and the missile.
C3	Warhead	The warhead of a missile provides its primary destructive power. Warheads are most commonly of the high explosive type, often employing shaped charges to exploit the accuracy of a guided weapon to destroy hardened targets.
C4	Speed	The highest speed at which a missile travels.
C5	Price	The cost incurred by the military industry to produce a missile.
C6	Production Capacity	The number of produced missiles in a year.

Table 4. The pairwise comparison matrix for criteria.

C	C1	C2	C3	C4	C5	C6
C1	(1, 1, 1)	(.26, .35, .58)	(.40, .66, 1.0)	(1.4, 1.8, 2.9)	(.29, .41, .58)	(1.1, 1.4, 2.4)
C2	(1.7, 2.8, 3.8)	(1, 1, 1)	(1.3, 2.0, 3.1)	(2.0, 3.1, 4.1)	(1.0, 1.5, 2.5)	(1.5, 2.2, 3.2)
C3	(1.0, 1.5, 2.5)	(.32, .50, .76)	(1, 1, 1)	(1.3, 2.3, 3.3)	(.45, .83, .90)	(1.0, 1.1, 2.1)
C4	(.34, .55, .71)	(.24, .32, .50)	(.30, .43, .76)	(1, 1, 1)	(.25, .33, .50)	(.31, .45, .66)
C5	(1.7, 2.4, 3.4)	(.40, .66, 1.0)	(1.1, 1.2, 2.2)	(2.0, 3.0, 4.0)	(1, 1, 1)	(1.4, 1.8, 2.9)
C6	(.41, .71, .90)	(.31, .45, .66)	(.47, .90, 1.0)	(1.5, 2.2, 3.2)	(.34, .55, .71)	(1, 1, 1)
S	8.96	3.28	6.19	13.4	4.62	7.95

Weapon ranks are determined by using fuzzy TOPSIS method in the third stage. Linguistic values are used for evaluation of weapons in this step. The membership functions of these linguistic values are shown at (Fig. 4), and the triangular fuzzy numbers related with these variables are shown at (Table 2). The missile system having the maximum CC_ivalue is determined as the optimal missile system according to the calculations by Fuzzy TOPSIS. Ranking of the other missile systems are determined according to CC_i in descending order.

Table 5. Weights of criteria.

Criteria	Weights (w)	Rank
C1	0.1265	5
C2	0.2837	1
C3	0.1628	3
C4	0.0693	6
C5	0.2265	2
C6	0.1308	4

Criteria to be considered in the evaluating the tactical missile systems are determined by the expert team. Past experience and the background of the expert team in usage are investigated and decision-making team determined five possible missile systems suitable for the needs. At the end of this case study, it turned out to be that these five missile systems do not have different characteristics with regard to all six criteria. After pairwise comparisons are finished at a level, a fuzzy reciprocal judgment matrix can be established as Table 4.

We can calculate the weights according to the fuzzy AHP methodology. The weight values presented in Table 5 reveal that the two most important performance criteria for weapon selecting were Guidance systems (0.2837) and Price (0.2265). In addition $\lambda_{max} = 6.089$, $CI = 0.017$. Consistency ratio of the pairwise comparison matrix is calculated as $0.0144 < 0.1$. So the weights are shown to be consistent and they are used in the selection process.

3.2. Evaluation of missile systems and determine the final rank

The fuzzy decision matrix for the five missile systems was filled by the decision makers in Table 7, using linguistic variables in Table 2.

Table 6. Weighted evaluation for the missile systems.

Missiles	C1	C2	C3	C4	C5	C6
M1	(.075, .101, .126)	(.170, .226, .283)	(.065, .097, .130)	(.055, .069, .069)	(.000, .045, .090)	(.000, .026, .052)
M2	(.050, .075, .101)	(.170, .226, .283)	(.097, .130, .162)	(.041, .055, .069)	(.000, .045, .090)	(.000, .000, .026)
M3	(.000, .025, .050)	(.113, .170, .226)	(.097, .130, .162)	(.027, .041, .055)	(.090, .135, .181)	(.026, .052, .078)
M4	(.050, .075, .101)	(.113, .170, .226)	(.065, .097, .130)	(.000, .013, .027)	(.135, .181, .226)	(.026, .052, .078)
M5	(.075, .101, .126)	(.170, .226, .283)	(.065, .097, .130)	(.013, .027, .041)	(.135, .181, .226)	(.000, .026, .052)
M^*	$\tilde{v}_1^* = (1,1,1)$	$\tilde{v}_2^* = (1,1,1)$	$\tilde{v}_3^* = (1,1,1)$	$\tilde{v}_4^* = (1,1,1)$	$\tilde{v}_5^* = (0,0,0)$	$\tilde{v}_6^* = (1,1,1)$
M^-	$\tilde{v}_1^- = (0,0,0)$	$\tilde{v}_2^- = (0,0,0)$	$\tilde{v}_3^- = (0,0,0)$	$\tilde{v}_4^- = (0,0,0)$	$\tilde{v}_5^- = (1,1,1)$	$\tilde{v}_6^- = (0,0,0)$

The next step is to obtain a fuzzy weighted decision table. Using the criteria weights calculated by AHP (Table 5) in this step, the Weighted Evaluation Matrix is established. The resulting fuzzy weighted decision matrix is shown in Table 6.

It is easy to see that the elements $\tilde{v}_{ij}, \forall\, i, j$ are normalized positive triangular fuzzy numbers and their ranges belong to the closed interval $[0, 1]$ (see Table 6).

Thus, we can define the fuzzy positive ideal solution (FPIS, A^*) and the fuzzy negative ideal solution (FNIS, A^-) as $\tilde{v}_i^* = (1,1,1)$ and $\tilde{v}_i^- = (0,0,0)$ for benefit criterion, and $\tilde{v}_i^* = (0,0,0)$ and $\tilde{v}_i^- = (1,1,1)$ for cost criterion. In this problem, C5 is cost criteria whereas the other criteria are benefit criteria. Consequently, the distance of each missile system from A^* and A^- can be currently calculated. The last step solves the similarities to an ideal weapon.

Based on CC_i values in Table 8, the ranking of the missile systems in descending order are M1, M2, M5, M3 and M4 (see Table 9). Proposed model results indicate that M1 is the best missile with CC_i value of 0.2466.

Table 7. Subjective cognition results of evaluators towards the six levels of linguistic variables.

	M1	**M2**	**M3**	**M4**	**M5**	**Weights (w)**
C1	(.6, .8, 1)	(.4, .6, .8)	(.0, .2, .4)	(.4, .6, .8)	(.6, .8, 1)	0.1265
C2	(.6, .8, 1)	(.6, .8, 1)	(.4, .6, .8)	(.4, .6, .8)	(.6, .8, 1)	0.2837
C3	(.4, .6, .8)	(.6, .8, 1)	(.6, .8, 1)	(.4, .6, .8)	(.4, .6, .8)	0.1628
C4	(.8, 1, 1)	(.6, .8, 1)	(.4, .6, .8)	(.0, .2, .4)	(.2, .4, .6)	0.0693
C5	(.0, .2, .4)	(.0, .2, .4)	(.4, .6, .8)	(.6, .8, 1)	(.6, .8, 1)	0.2265
C6	(.0, .2, .4)	(.0, .0, .2)	(.2, .4, .6)	(.2, .4, .6)	(.0, .2, .4)	0.1308

Table 8. Fuzzy TOPSIS results.

missiles	**D_i^***	**D_i^-**	**CC_i**
M1	4.5459	1.4887	0.2466
M2	4.5653	1.4684	0.2433
M3	4.7253	1.3047	0.2163
M4	4.7790	1.2485	0.2071
M5	4.7096	1.3178	0.2186

Table 9. Weighted and unweighted rankings.

Weighted CC_i	**Weighted ranking**		**Unweighted CC_i**	**Unweighted ranking**
0.2466	M1		0.6661	M1
0.2433	M2		0.6249	M2
0.2186	M5		0.5048	M4
0.2163	M3		0.5000	M3
0.2071	M4		0.5000	M5

The case in which criteria weights are not considered, i.e., the criteria have equal priorities, is analyzed and the CC_i values obtained in this condition are presented in Table 9 with their comparisons with previous values. Based on unweighted CC_i values, the ranking of the missile systems in descending order are M1, M2, M4, M3 and M5 (see Table 9). The best missile system has not changed according to the unweighted ranking results. The change in the ranking of missile systems when criteria weights are taken into account has shown that criteria weights found consistently important phase in decision-making process.

4. Conclusion

This study, presenting a scientific framework to evaluate missile systems, uses triangular fuzzy numbers to express linguistic values that consider the subjective judgments of evaluators and then adopts fuzzy multiple criteria decision-making approach to synthesize the group decision. In fact, the fuzzy AHP is used to determine the preference weights of evaluation. Then, the weights are adopted in fuzzy TOPSIS to improve the gaps of missile systems between real performance values and achieving aspired levels in each criterion and find out the best missile system for achieving the aspired/desired levels based on five tactical missile systems. It should be noted that we do not direct given scores by experts, we built membership functions by data of missile performance to calculate the grade values, and we use the grade values to represent the performance scores.

The proposed model may contribute to satisfying the demands for rationality and transparency in defense expenditures by strengthening the underlying rationale behind military procurement decisions. The model can also be used with slight modifications in other decision-making problems in Defense Industries of different countries. In addition, mathematical models can be combined with this model. This will improve the methods and is one of the directions in our future research.

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