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Military Application of Multi-Criteria Decision Making

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Which is the most appropriate military device for the army based on user interest? This is a frequently asked question. In this paper I will show two methods that can help to select the best one based on the Decision Maker or the user interest and point of view.
Keywords: *military device, decision theory*

Introduction

In this paper I will show an application of a special class of the Decision Theory, this is the Multi-Criteria Decision Making (MCDM). [1] [2] The aim of this study is to describe how the MCDM functions in the military field. The application of MCDM is shown by a case study.

I selected five types of Anti-Tank Missiles (ATM) for the evaluation, and I also selected two MCDM approaches that seemed to be applicable. Using these two models two compari- sons were carried out and two rankings were achieved.

I show the appropriate application of MCDM through these case studies, including the criteria hierarchy, the weighting and the calculating of the overall scores.

The MCDM is a special class of the Decision Theory and it has special properties. The most important characteristic of MCDM is the multiple point of view of the Decision Maker. The Decision Maker has a special aim to achieve, but there are many modes of achievement. This is the basis of the decision problem. The task of the decision maker is to choose the best way to achieve his aim but the decision maker's aim is complex. He not only wants the best solution but he wants an optimal solution where the advantages and the disadvantages of the course of actions are balanced. Let me take the example of buying a car. A car has many properties, for instance speed, fuel consumption, size, trunk, ergonomics, aesthetics, safety and so on. The decision maker not only wants the speediest car but he wants a car that has optimal characteristics based on the decision maker's interest. The optimal solution can fulfil the decision maker's complex aims with better quality than the others.

The process of the MCDM consists of the following steps:

1. Identification of the decision problem;
2. Identification of the Decision Maker's aims;
3. Gathering the alternatives;
4. Definition of criteria;
5. Weighting of criteria;
6. Selection of the proper MCDM model;
7. Application of the selected MCDM model;
8. Estimation of results.

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Identification of the Decision Problem

On one hand, the ATM with Infrared Homing (IH) guidance system was applied successfully and effectively in the last decade in Iraq and in Afghanistan. On the other hand, there are great numbers of Anti-Tank missiles with Wire guided Semi-Automatic Command to Line Of Sight (WSACLOS) guidance systems in service in the European armies and its manufac- turers have upgraded many WSACLOS ATM systems.

There is a huge difference between these systems. The IH ATMs have great effectiveness at very high cost; the WSACLOS ATMs have a lower cost but they also have a relatively medium or unknown effectiveness in comparison with the IH ATMs.

Identification of the Decision Maker's Aims

The Decision Maker wants to know which is the most appropriate solution including the effectiveness and the cost together. Therefore he wants to compare the following systems:

- Infrared Homing Anti-Tank Missiles;
- Upgraded WSACLOS Anti-Tank Missiles;
- Conventional WSACLOS Anti-Tank Missile.

Gathering the Alternatives

Five ATMs were selected for the comparison. In order to avoid the impression of commercial advertising, the manufacturers of the ATMs and the types cannot be named. Two IHs and two upgraded WSACLOSs and a conventional WSACLOS system were selected, they are: IH 1; IH 2; UW 1; UW 2; CW 1.

Definition of Criteria

The main criteria are always complex and may be broken down into lower levels called sub-criteria, and if it is necessary the sub-criteria may be broken down too until the sub-cri- terion can be measured objectively or subjectively. Therefore these criteria always form a hierarchy. Building up this hierarchy is a complex task and it takes a lot of time and expe- rience. Therefore I selected a finished one that contains the [3] source. Figure 1 shows the criteria hierarchy.

Weighting of Criteria

There exist two kinds of models for the weight calculation: the objective and the subjective. The objective methods based on the dispersion of the alternative's values which belong to the same criterion but they need a lot of data. The subjective methods are based on a pair- wise-comparison and they need experienced experts, therefore I use [3] source's weight, that is shown by Figure 1.

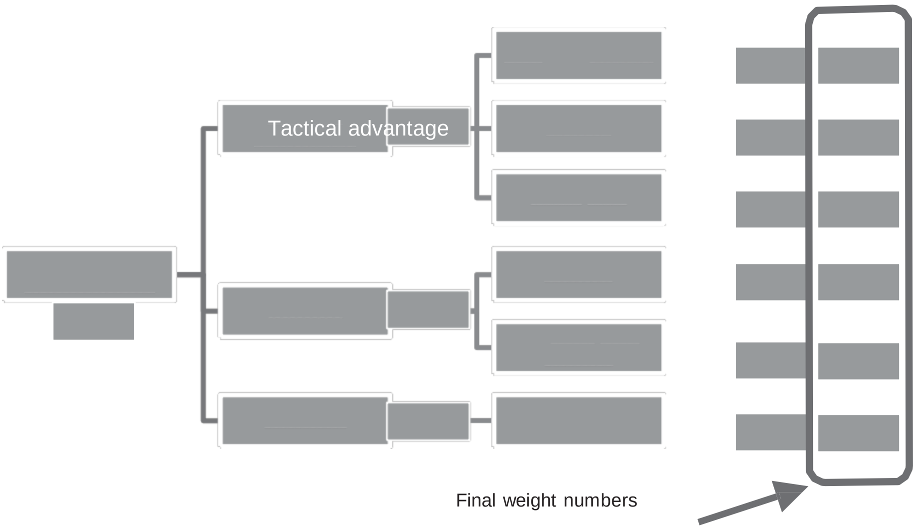

Figure 1. Criteria hierarchy. [3]

Selection of the Proper MCDM Model

The MCDM models have different characteristics, therefore to select from them is a MCDM problem too. The most important points of view in the selection are the following:

- laws;
- goals of the Decision Maker;
- properties of alternatives;
- available sources (founding, experts);
- available data.

The most important aim of this paper is to show how the MCDM functions in the military field, therefore I have selected two models for the comparison, the PROMETHEE [4] and the TOPSIS. [1]

Application of the Selected MCDM Model

Application of PROMETHEE

Computation of Preferences Degrees for Every Pair of Alternatives on Each Criterion

The PROMETHEE uses preference functions but the function's variables are not the alterna- tive's value but the difference between two alternative's value based on the same criterion, therefore this model scores the differences. Equation 1 shows the preference function and Table 2 shows the ATMs' weight and Table 3 shows the calculated preferences among the alternatives based on the Weight criterion.

$$p(a,b) = \begin{cases} 0 & | d \leq q \\ {d - q}/{p - q} & | q < d < p \\ 1 & | d \geq p \end{cases} \qquad \text{Eq 1}$$

where *p*: preference degree; *p*, *q* thresholds; *d*: differences between the alternative's value. Source: [1]

Table 1. Weight of the ATMs (to be minimized). [Source: author's own work]

IH 1	UW 1	CW 1	UW 2	IH 1
22,3 kg	36,7 kg	28 kg	35 kg	26 kg

Table 2. Preference degrees of weight criterion. [Source: author's own work]

	IH 1	**IH 2**	**UW 1**	**CW 1**	**UW 2**
IH 1		0.26	1	0.4	0.88
IH 2	0		0.74	0.14	0.38
UW 1	0	0		0	0
CW 1	0	0	0.6		0.49
UW 2	0	0	0.12	0	

The preference degrees are calculated with the Equation (1) using the data of Table 1. The threshold are 0 and 14.8 kg, and the differences are calculated with *d = – (a–b)* because the weight is a minimized criterion where the smaller is the better.

Computation of Unicriterion Flows

Matrixes containing the preference degree are multiplied by their weight and these matrixes are added together. The positive flows are calculated by the sum of the aggregated matrix element of rows and the negative flows are calculated by the sum of element of columns. These are shown by Table 3. A rank can be interpreted by the positive and the negative flows. An alternative solution is better than the other, if the positive flow is better and the negative flow is smaller than the other.

Computation of Global Flow

The global flow is calculated by the positive flow minus the negative flow. It is shown by Figure 2 and Table 3 which is the result of the calculation.

Table 3. Unicriterion and Global flows. [Source: author's own work]

	Φ+	**Φ-**	**Φ**
IH 1	0.556	0.011	0.545
IH 2	0.518	0.021	0.497
UW 1	0.186	0.306	– 0.121
UW 2	0.053	0.438	– 0.536
CW 1	0.041	0.576	– 0.385

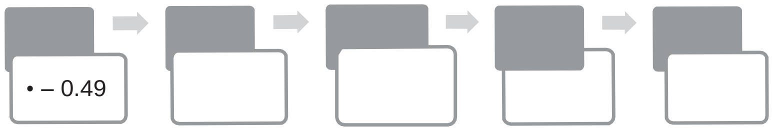

Figure 2. The result of PROMETHEE. [Source: author's own work]

Application of TOPSIS

Normalization of the decision matrix

There exist a lot of normalization methods, for instance: vector normalization, linear and non-linear normalization techniques. The TOPSIS method's most frequently used normaliza- tion technique is the following based on [5].

$$a_{ij} = \frac{|v_{ij}-T_j|}{\max\{\max_i v_{ij};T_j\}-\min\{\min_i v_{ij};T_j\}} \qquad \text{Eq 2}$$

where: i^{th} alternative's normalized value based on j^{th} criterion
: a j^{th} criterion's target values
: i^{th} alternative's value based on j^{th} criterion
$i = 1…5$; $j = 1…6$
The normalized decision matrix is shown by Table 4.

Table 4. Normalized decision matrix. [Source: author's own work]

	FF i/n	**Range [m]**	**Crew**	**Kill probability**	**Weight [kg]**	**Air drop y/n**
IH 1	0.315	0.045	0.045	0.35	0.15	0.05
IH 2	0.315	0.045	0.045	0.35	0.111458	0.05
UW 1	0	0.09	0	0.291667	0	0
CW 1	0	0	0	0	0,090625	0
UW 2	0	0.018	0	0.291667	0.017708	0
PIS	0.315	0.09	0.045	0.35	0.15	0.05
NIS	0	0	0	0	0	0

Computation of positive and negative ideal solution

The TOPSIS defines a positive ideal solution (PIS) and the negative ideal solution (NIS) and both of them are virtual alternatives. The PIS contains the maximum element of each column of the normalized decision matrix and the NIS contains the minimum element of the normal- ized decision matrixes based on Table 4.

Computation of Distances

The TOPSIS uses Euclidean distances to measure the overall effectiveness of the alternative solutions with the following notes:

$$C_i = \frac{D^-_i}{D^+_i + D^-_i} \qquad \text{Eq 3}$$

where D^-_i
D^+_i distance between the *i*
The results are shown by Figure 3.

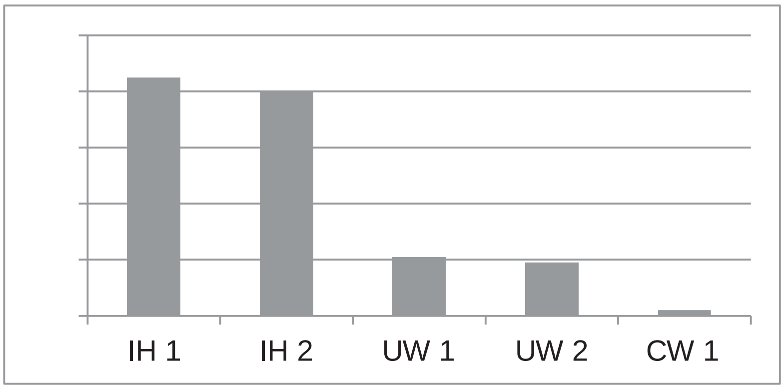

Figure 3. Result of TOPSIS. [Source: author's own work]

Summary

I got two results with the two different MCDM modes. The preference rankings are same on Figure 2 and Figure 3, but the differences between the UW1 and the UW 2 alternative solu- tions are small on Figure 3.

If we examine the processes of the solutions we can deduce the following:

- the models of MCDM are applicable in the military field, and the preference order among the military devices can be calculated;
- there exist numerous MCDM models with different characteristics and the different models need different decisions and estimations by the Decision Maker;
- in this case the two rankings were the same, but it does not mean that it is true in all cases;
- using different models can give different results with different information.

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