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Research Article

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Application of AHP and TOPSIS Methods on an Automobile Selection Problem

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Abstract Today, the variety of goods in markets makes the consumers face the problem of making a decision with respect to several criteria. Automobile market is also one of these markets that offer many alternative brands and models to its consumers. Specific features of cars such as price, safety, ease of use, fuel consumption, etc. influence the customers in their decision making problem. Consequently, buying a car becomes a multi-criteria decision making problem. In this study, we analyze this problem with respect to certain automobile features and compare four popular car models with each other. We apply two different multi-criteria decision making methods, AHP (Analytical Hierarchy Process) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution). Our results show that two methods give two different orderings of car models and this shows that it may not be a good strategy to use only one decision making method in multi-criteria decision making problems.

Keywords AHP, TOPSIS, car selection, multi-criteria decision making methods

1. Introduction

Decision making and finding the best alternative among a set of available alternatives have been an important concern of people since the beginning of history. Regardless of the seriousness of the decision problem, (Ex. choosing the color of a dress versus making a tactical move in a war), we always want to find the best option among a set of available ones. Unfortunately, most of the time decision making is not an easy process due to the conflicting criteria/requirements we have in our decision problem. For example, we may want to pay minimum money for a product, but at the same time we may want it to have the highest quality and several features. These conflicting constraints make decision problems harder.

It is for sure that we can easily compare quantitative characteristics of products. There is no problem in determining weights, colors, quantities, toughness, etc. kind of features of products. Consequently it is easy to rank alternatives based on quantifiable features, or simply numbers. However, in many decision making problems, it is not easy to find a numerical term that represents/measures a certain feature of a product. For example, what is the measure for the comfort of a hotel? This is something that is subjective and may change depending on the person. In order to overcome the subjectivity and vagueness in decision problems, the general approach in decision making problems is to use specific algorithms/methods assigning a quantitative score to each decision alternative so that the relative ranking of alternatives becomes possible. In this study, we use such two different algorithms AHP (Analytical Hierarchy Process) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) for an automobile selection problem. The details of the problem and the algorithms are given in the next section.

2. Problem Definition and Methodology

We analyze an automobile selection problem among four different car models. These models are currently popular in Turkey and they are evaluated according to seven difference performance criteria (measure) and the scores for these performance measures are given by experts and these data are available at the website www.sifiraracal.com. In Figure 1, the hierarchical model for these four different car models with respect to the selected seven difference performance criteria is given.

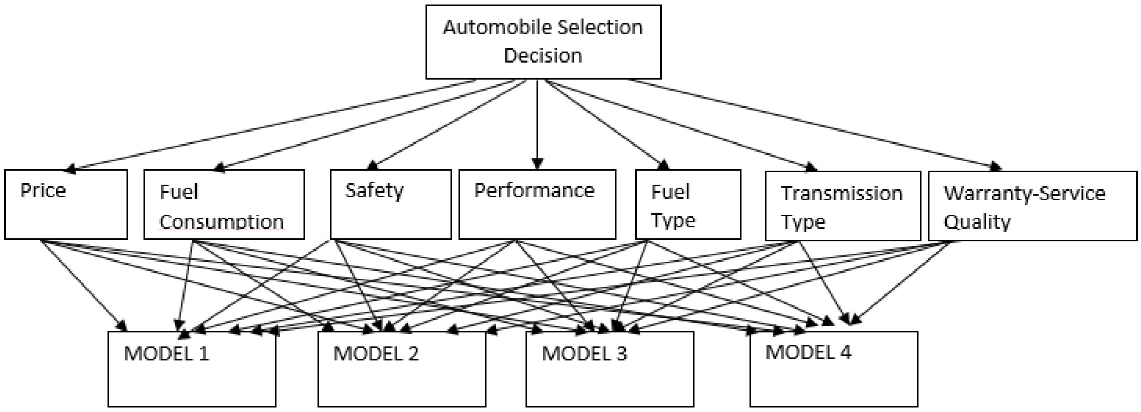

Figure 1: Hierarchical Model

Our purpose is to find the best car model among the four available ones with respect to seven different performance measures. In order to do this, we apply two different algorithms that are explained in the next sections.

2.1 AHP Method

AHP method was first mentioned by [1] and later improved by [2]. According to this method, initially each performance measure is compared to each other and a matrix that shows the relative importance of performance measures with respect to each other is formed. Later on, each selection alternative is compared to each other with respect to each performance measure. For each performance measure, if the measure is quantitative (such as price), the pairwise comparison can be done directly. However, if the measure is qualitative (such as comfort), then these qualitative measures can be converted to quantitative numbers as described in [3] and then the pairwise comparison matrices can be formed for each performance measure. In the next step, these pairwise comparison matrices are normalized and weight vectors (w) are found. The Weight matrix (W) formed by combining w vectors of the alternative comparison matrices is multiplied by the w vector of the performance criteria comparison matrix and a ranking of the alternatives are obtained. Also the calculations are tested for consistency by consistency calculations. The details of the AHP algorithm can be found in [3].

In this study, when we apply the AHP algorithm we obtain the below comparison matrices shown in Tables 1 to 8:

Table 1: Performance Criteria Comparison Matrix

	Price	**Fuel Consumption**	**Safety**	**Performance**	**Fuel Type**	**Transmission Type**	**Warranty-Service Quality**
Price	1.000	3.000	3.000	3.000	5.000	5.000	7.000
Fuel Consumption	0.333	1.000	3.000	3.000	3.000	5.000	7.000
Safety	0.333	0.333	1.000	3.000	3.000	3.000	5.000
Performance	0.333	0.333	0.333	1.000	3.000	3.000	5.000
Fuel Type	0.200	0.333	0.333	0.333	1.000	3.000	3.000
Transmission Type	0.200	0.200	0.333	0.333	0.333	1.000	3.000
Warranty-Service Quality	0.143	0.143	0.200	0.200	0.333	0.333	1.000

Table 2: Alternative Comparison Matrix with respect to Price

PRICE	**MODEL1**	**MODEL2**	**MODEL3**	**MODEL4**
MODEL1	1.000	4.000	7.000	9.000
MODEL2	0.250	1.000	4.000	7.000
MODEL3	0.143	0.250	1.000	3.000
MODEL4	0.111	0.143	0.333	1.000

Table 3: Alternative Comparison Matrix with respect to Fuel Consumption

FUEL CONSUMPTION	MODEL1	MODEL2	MODEL3	MODEL4
MODEL1	1.000	2.000	0.143	0.200
MODEL2	0.500	1.000	0.143	0.200
MODEL3	7.000	7.000	1.000	2.000
MODEL4	5.000	5.000	0.500	1.000

Table 4: Alternative Comparison Matrix with respect to Safety

SAFETY	MODEL1	MODEL2	MODEL3	MODEL4
MODEL1	1.000	0.333	0.250	0.200
MODEL2	3.000	1.000	0.500	0.250
MODEL3	4.000	2.000	1.000	0.500
MODEL4	5.000	4.000	2.000	1.000

Table 5: Alternative Comparison Matrix with respect to Performance

PERFORMANCE	MODEL1	MODEL2	MODEL3	MODEL4
MODEL1	1.000	0.200	0.500	0.200
MODEL2	5.000	1.000	5.000	0.500
MODEL3	2.000	0.200	1.000	0.200
MODEL4	5.000	2.000	5.000	1.000

Table 6: Alternative Comparison Matrix with respect to Fuel Type

FUEL TYPE	MODEL1	MODEL2	MODEL3	MODEL4
MODEL1	1.000	0.500	0.200	0.200
MODEL2	2.000	1.000	0.200	0.200
MODEL3	5.000	5.000	1.000	2.000
MODEL4	5.000	5.000	0.500	1.000

Table 7: Alternative Comparison Matrix with respect to Transmission Type

TRANSMISSION TYPE	MODEL1	MODEL2	MODEL3	MODEL4
MODEL1	1.000	0.200	0.500	0.200
MODEL2	5.000	1.000	4.000	0.500
MODEL3	2.000	0.250	1.000	0.200
MODEL4	5.000	2.000	5.000	1.000

Table 8: Alternative Comparison Matrix with respect to Warranty-Service Quality

WARRANTY-SERVICE QUALITY	MODEL1	MODEL2	MODEL3	MODEL4
MODEL1	1.000	2.000	3.000	3.000
MODEL2	0.500	1.000	2.000	3.000
MODEL3	0.333	0.500	1.000	2.000
MODEL4	0.333	0.333	0.500	1.000

The comparison matrices pass the consistency test according to our calculations. After applying AHP procedure, we find the following ranking of models as shown in Table 9, stating that automobile Model 4 is the best alternative to choose.

Table 9: Ranking of Car Models as a result of AHP

	Ranking
MODEL1	0.268
MODEL2	0.199
MODEL3	0.256
MODEL4	0.277***

2.2 TOPSIS Method

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method was generated by Hwang and Yoon [4]. This method is based on ranking the alternatives with respect to their distance to the ideal solution.

The algorithm starts with constructing a mxn decision matrix where the rows correspond to the alternatives and the columns correspond to the performance measures. Based on this decision matrix, a standard decision matrix (*N*) is formed using equation (1):

$$n_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \qquad i = 1 \dots m, j = 1 \dots n \qquad (1)$$

In equation (1) a_{ij} stands for the the element i^th^ row j^th^ column element of the decision matrix and n_{ij} is the i^{th} row j^{th} column element of the standard decision matrix*N*. Standard decision matrix *N*'s each element in the j^{th} row is multiplied with a weight w_j which shows the relative weight the decision maker gives to the j^{th} performance measure. The total of all weights should be equal to 1. After multiplying Matrix *N* elements with respective weights, the weighted standard decision matrix (*V*) is obtained. As v_{ij} shows i^{th} row j^{th} column element of the weighted standard decision matrix *V*, the best (A^+) and worst solution (A^-) sets containing the best and worst solution for each performance measure are found according to equations (2) and (3), respectively.

$$A^+ = \{max_{i\in 1\dots m} v_{ij} \,|j \in 1 \dots n\} = \{v_1^+, v_2^+, \dots, v_n^+\} \qquad (2)$$

$$A^- = \{min_{i\in 1\dots m} v_{ij} \,|j \in 1 \dots n\} = \{v_1^-, v_2^-, \dots, v_n^-\} \qquad (3)$$

Then using equations (4) and (5), the distance of each selection alternative to the best and worst solutions are obtained, respectively.

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2} \qquad i \in 1 \dots m \qquad (4)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \qquad i \in 1 \dots m \qquad (5)$$

These distance values are used to calculate the relative closeness of alternative *i* to the ideal solution (C_i^+) as shown by equation (6).

$$C_i^+ = \frac{S_i^-}{S_i^- + S_i^*} \qquad i \in 1 \dots m \qquad (6)$$

As C_i^+ value is closer to 1, this shows that i^{th} alternative is closer to ideal solution.

In order to start TOPSIS method, the weight vectors (*w*) found in AHP for alternative comparison matrices is used to construct the decision matrix shown in Table10.

Table 10: Decision Matrix Using equation (1), the standard decision matrix is formed as shown in Table 11.

DECISION MATRIX (A)	PRICE	FUEL CONSUMP.	SAFETY	PERFORMANCE	FUEL TYPE	TANSMISSON TYPE	WARRANTY-SERVICE QUALITY
MODEL1	0.606	0.087	0.073	0.071	0.071	0.072	0.445
MODEL2	0.256	0.061	0.157	0.344	0.101	0.330	0.283
MODEL3	0.093	0.533	0.276	0.101	0.483	0.107	0.165
MODEL4	0.044	0.319	0.494	0.483	0.344	0.492	0.107

Table 11: Standard Decision Matrix

STANDARD DECISION MATRIX (N)	PRICE	FUEL CONSUMPTION	SAFETY	PERFORMANCE	FUEL TYPE	TANSMISSON TYPE	WARRANTY-SERVICE QUALITY
MODEL1	0.910	0.138	0.123	0.117	0.117	0.119	0.791
MODEL2	0.384	0.097	0.265	0.568	0.167	0.544	0.503
MODEL3	0.140	0.846	0.466	0.167	0.797	0.176	0.293
MODEL4	0.066	0.506	0.835	0.797	0.568	0.811	0.190

Relative weights of performance criteria (w_i) are obtained using the weight vector of performance criteria comparison matrix (given in Table 1) formed in AHP. Multiplication of standard decision matrix with these weight factors gives the weighted standard decision matrix as shown in Table 12.

Table 12: Weighted Standard Decision Matrix

WEIGHTED STANDARD DECISION MATRIX (V)	PRICE	FUEL CONSUMPTION	SAFETY	PERFORMANCE	FUEL TYPE	TANSMISSON TYPE	WARRANTY-SERVICE QUALITY
MODEL1	0.310	0.032	0.019	0.014	0.009	0.006	0.022
MODEL2	0.131	0.022	0.041	0.067	0.012	0.028	0.014
MODEL3	0.048	0.196	0.073	0.020	0.059	0.009	0.008
MODEL4	0.023	0.117	0.130	0.094	0.042	0.041	0.005

Using Equations (2) and (3), the best and worst solutions are obtained for each performance measure as in Table 13.

Table 13: Best - Worst (The Most Positive and Negative) Solutions for Performance Measures

Criteria	$A+$	$A-$
PRICE	0.310	0.023
FUEL CONSUM.	0.196	0.022
SAFETY	0.130	0.019
PERFORMANCE	0.094	0.014
FUEL TYPE	0.059	0.009
TRANSMISSION	0.041	0.006
WARRANTY-SE.	0.022	0.005

Using Equations (4) – (6), the final scores are found as in Table 14. As a result of TOPSIS, Model 1 is found to be the best alternative among available ones.

Table 14: TOPSIS Solutions

Alternative	S^+	S^-	C_i^*
MODEL 1	0,222	0,288	**0,565 *****
MODEL 2	0,270	0,125	0,316
MODEL 3	0,281	0,191	0,405
MODEL 4	0,299	0,174	0,368

3. Conclusion and Remarks

Our results show that AHP algorithm finds car Model 4 as the best one among the available models, whereas according to TOPSIS algorithm Model 1 is the best choice. In fact Model 1gets a ranking score (0.268) closer to Model 4 score (0.277) in AHP which means that according to AHP Model 1 can also be a good alternative. However, the reverse is not true. TOPSIS results show that Model 1 has a relatively high ranking score compared to other models and Model 4's ranking score is not very high. From the most important to the least important one, the relative importance of performance criteria is ordered as price, fuel consumption, safety, performance, fuel type, transmission type, and service.

This study shows that different multi-criteria decision making methods may end up with different solutions for the same data set. We can conclude that it is not a good practice to use only one decision making algorithm before making a critical decision.

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