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Sensitivity analysis Decision techniques and weighting techniques in multiple attribute decision making Case Study (priority public transport systems in Qom)

Hadi MERATI[1,*], Abdolreza SHEIKHOLESLAMI[2]

[1]*MSc of transportation planning at Iran University of Science and Technology*
[2]*Assistant Professor of Iran University of Science and Technology*

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Abstract. In recent years, academic societies have to pay more attention to the decision-making techniques and much academic research in this field has been done, but in choosing the appropriate decision, especially in the case of multi-criteria decision-making, Studies are not enough. This paper examines real case shows that the type of technique used, in both weight and in the decision-making Undeniable impact on the rankings achieved, It also specifies how to rank the resulting decisions using various methods to compare and evaluate them. This article describes three methods of multi-criteria decision-making methods of the decision of the three subsidiaries(SAW method of subset grading and Rating, TOPSIS method of subset compromise and ELECTRE method of subset Coordination) and Three methods of weighting factors(Entropy technique, AHP Technique and the combination of entropy and AHP techniques) Is evaluated. The assessment in the case of the city of Qom, in order to prioritize public and suburban transport system of the city is studied **.**According to the survey, the results of entropy techniques among different methods of weighting, is not a very stable And the results of the decision-making techniques, SAW, high relative stability compared to other techniques, this means that the results of this technique is low sensitivity to the weighting.

Keywords: Sensitivity Analysis, multiple attribute decision making, Decision-making techniques, Weighting techniques, Spearman's rank correlation coefficient

1. INTRODUCTION

In today's world, most of the issues presented for decision-making to managers of various dimensions and is formulated with several variables. In other words, can not be optimizing by a variable, the final decision adopte. Naturally, the resolution of such issues is complex and not easily. Especially since many variables are in conflict and increase the utility of a variable, can reduce the utility of other variables. For this reason, methods have been developed as multiple attribute decision making to help solve the problems. This paper seeks to address that in a particular case (the prioritization of public transport and suburban Qom) the difference between the results of the techniques used to determine the sensitivity of the response (prioritized options) technique used to examine

2. HISTORY

It's a multi-criteria decision in principle can be summarized in a decision matrix that rows the various options, and index columns that define the characteristics of the options. The cells in the matrix, the Row option to show the relevant column index [1].Then prioritize the options is based on the matrix. The decision to prioritize the need for a technique to determine the best options evaluated by comparing indicators. another issue discussed is the weight index that utilizes the techniques of weighting, the weight of each index are determined. In this way, the multi-criteria decision-making problem facing with two problems: 1) selection of decision techniques 2) selection of weighting techniques.Hwang and Yoon, in his book introduces many techniques in this field but perhaps the most widely used of these techniques are presented as follows [12]: Decision-making techniques: simple additive weighthing method(SAW), technique for order

* Corresponding author. *Email address: hadimerati1@gmail.com*

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preference by similarity to ideal solution(TOPSIS),elimination et choice translating reality(ELECTRE)

Weighting techniques: analytic hierarchy process (AHP), entropy and combination of entropy and AHP.

In this paper, the algorithm description of these methods is not desired and the subject matter of this article, a comparison and analysis of the sensitivity of the response from the use of these methods. A sensitivity analysis of the results of the application of multi-criteria models by a number of researchers and a wide range of views was conducted. Wolter and Marshall, including the analysis of three different approaches that are [11]:

1- Votes sensitivity analysis to changes in the evaluation of all options for a particular indicator.
2- The sensitivity analysis to changes in the evaluation ratings for a particular option
3- the required minimum weights, measures that will lead to the replacement of superior options

The results of the analysis have shown that the first two of the above analysis, the applicability of multi-criteria decision making in dynamic environments increases and the third is a tool to analyze sensitive index weights.

Antunes and Climaco believe that a sensitivity analysis of the results, evaluation criteria should be made to the weights and every time the results of the decisions said to his knowledge so he could provide more favorable [7].

Another type of sensitivity analysis of multi-criteria decision-making models that Kasanan and others have done sensitivity analysis with respect to the use of these models in organizations. It is believed that if the decision is not just about selecting multiple criteria, but also to create options, determine the importance of standards, support the decision-making as it is, the better response is achieved[8].

3. DEFINITION OF THE PROBLEM

One of the important issues in the field of urban transport planning is necessary to select suitable transport systems that serve the various aspects to be improved. In order to select an optimal system with regard to the evaluation of a variety of different techniques can be used the results of these techniques are not necessarily one and can have significant differences with each other. In this study, the sensitivity analysis results from the use of various techniques, prioritization of urban and suburban transport systems Qom is considered. Based on field studies conducted in the city of Qom, the city consists of four option-style LRT, monorail, BRT and regular bus system to develop public transport systems are considered[5,6].The evaluation criteria used to compare these four options is also included 12 cases: Capacity, speed, , headway, investment costs, maintenance costs, energy consumption, noise pollution, air pollution, safety, ease of access, namespace, and the time required to build the system.[4]

According to the above description and field studies, options and indices for evaluating the decision matrix is formed. This matrix in Table 1 is presented.

Table 1. Matrix decision provided for Qom [2].

energy consumption(watt hour/km-passenger)	time required to build the system(months for construction of a km)	maintenance costs(cent/km–passenger)	investment costs(millions of dollar/km)	Namespace(m)	Safety(dollar)	ease of access(m)	noise pollution(db)	passenger -) air pollution(gr/100km	Headway(s)	Speed(h/km)	(per hour person) Capacity	index / system
31	5	80	20	2.9	15171	1300	75	0.01	240	40	9000	monorail
31	4.5	30	63.3	0.01	15171	880	0.01	0.01	120	31.6	17500	LRT
44.5	0.3	20	2.75	3.5	35081526	870	89	200	60	30	17500	BRT
59.6	0.2	26	0.65	3.65	35081526	870	89	268	383	16.7	10000	Regular bus

4. PROBLEM SOLVING

Problem solving consists of two parts weighting sensitivity analysis techniques and sensitivity analysis techniques combined weighting and prioritization techniques that follow.

4.1. Sensitivity analysis techniques weighting

To calculate the index weights estimation, entropy techniques, AHP, and the combination of these two techniques have been used. Entropy algorithm based on numerical analysis techniques that only the information in the decision-making matrix to determine the weights of evaluation indicators while the hierarchical analysis, expert opinions transport determines the weights of indicators will be assessed. The results of the application of these techniques to the problem mentioned in Table 2 are shown.

Table 2. Results of the evaluation index weights calculated values using various techniques.

energy consumption	time required to build the system	maintenance costs	investment costs	Namespace	Safety	ease of access	noise pollution	air pollution	Headway	Speed	Capacity	index / Technique
0.007	0.101	0.018	0.146	0.127	0.13	0.003	0.269	0.135	0.044	0.008	0.009	Entropy[3]
0.078	0.055	0.036	0.106	0.047	0.18	0.058	0.064	0.111	0.072	0.072	0.109	AHP[3]
0.006	0.062	0.007	0.172	0.066	0.27	0.002	0.191	0.166	0.035	0.007	0.011	combination of entropy and

The third technique results in Table 2 (combination of entropy and AHP) were obtained using Equation 1.

$$W_j = \frac{v_j \times u_j}{\sum_{j=1}^{n} v_j . u_j}$$

Equation 1

In Equation 1: Wj of the final weight of the composition of entropy and AHP, vj weights using the technique of entropy and uj weights using the AHP method[1]. As in Table 2 can be seen, the results of weighting techniques, different and use the results of each of these techniques in the decision-making process will lead to different results. In order to compare the results of different methods of weighting the Spearman correlation coefficient was used.

4-1-1- Spearman's rank correlation coefficient

In this way, the first assessment indicators in each of these techniques are in decreasing order and then a marked difference in ranking in the index compared the two techniques (di) and using equation (2) will be calculated Spearman correlation coefficient values [9].

$$R_s = 1 - \frac{6 \sum d_i^2}{n(n^2-1)}$$

Equation 2

In Equation 2: Rs, Spearman correlation coefficient,di Rating difference of two compounds and n is the number of indicators. The correlation coefficient obtained for techniques in the table (3) is shown.

Table 3. Spearman correlation coefficients were calculated for weighting techniques.

Spearman's rank correlation coefficient	Technique
0.2098	AHP And Entropy
0.3811	AHP and AHP- Entropy
0.9476	Entropy and AHP– Entropy

As shown in Table (3) observed correlation techniques combined entropy and entropy and AHP technique is very high(0.9476) .This suggests that the results of these two techniques are very close together and while the correlation between entropy and AHP technique is much lower(0.2098) Indicating the lack of consistency in the results of the two techniques together. In order to determine the exact amount of correlation between these three techniques using t-test 2n-2 = 22 degrees of freedom and a = 0.05 can be used. The basic assumption in this case is the lack of correlation between the two techniques. The results of this test in the table (4) is shown[10]

Table 4. The correlation weighting techniques using t-test.

Correlation status	Technique
Lack of correlation	AHP And Entropy
correlation	AHP and AHP- Entropy
correlation	Entropy and AHP– Entropy

According to the results, we can conclude that:

- ✓ The results of the two techniques, entropy and AHP, are not correlated. In other words, the results of these techniques are very different from each other and decide if the use of these techniques, different results will follow.
- ✓ The results of combining the techniques of entropy and AHP, with the results of entropy techniques, with a high correlation. In other words, the equation used to combine the results of the two techniques (equation (1)) in such a way that the results are closer to the results of

entropy techniques and that is why the results of the combined entropy techniques and AHP, with the results of the technique AHP, has a low correlation.

4-2- Sensitivity analysis techniques combined weighting and prioritization

In order to prioritize the options (transportation systems), methods of decision-making and weighting in 9 forms is used and finally the results are analyzed and compared with each other. Compounds used are as follows:

Combine 1. AS: weighted with AHP and prioritize with SAW

Combine 2. AT: weighted with AHP and prioritized with TOPSIS

Combine 3. AE: weighted with AHP and prioritization with ELECTRE

Combine 4. ES: weighted with entropy and prioritization with SAW

Combine 5. ET: weighted with entropy and prioritization with TOPSIS

Combine 6. EE: weighted with entropy and prioritization with the ELECTRE

Combine 7. AE-S: weighted with combine of entropy and AHP and prioritization with SAW

Combine 8. AE-T: weighted with combine of entropy and AHP and prioritization with TOPSIS

Combine 9. AE- E: weighted with combine of entropy and AHP and prioritization with ELECTRE

With regard to the above compounds, 9 priority is obtained in the table (5) is shown.

Table 5. The results of the prioritization of options using different combinations.

AE-E	AE-T	AE-S	EE	ET	ES	AE	AT	AS	combination of decision / system
1	1	1	1	1	1	2	3	1	LRT
2	2	2	2	2	2	1	2	2	monorail
3	3	4	4	3	4	3	4	4	BRT
4	4	3	3	4	3	4	1	3	BusRegular

Now the question is how to compare the results of this prioritization? and whether it can be almost the same as the valid or not. To answer this question the following approaches can be used.

4-2-1- Euclidean distance

In this approach, the ratings obtained in the previous stage, are compared with each other and eventually obtained 36 comparable pairs. The result of this comparison in the table (6) is shown. How to Calculate the difference, based on Euclidean distance. For example, to calculate the difference between the ratings of both AS and ET, different ratings for each of the options that are earned in each of the two methods and then be square. The square root of the sum of the squares, defines the difference between AS and ET's Rating.

Table 6. Values are a couple different ways of prioritizing using the Euclidean distance approach.

Row	Techniques compared	Euclidean distance	Row	Techniques compared	Euclidean distance
1	(ES)-(ET)	1.41	19	(EE)-(AE-S)	0
2	(ES)-(EE)	0	20	(EE)-(AE-T)	2
3	(ES)-(AS)	0	21	(EE)-(AE-E)	1.41
4	(ES)-(AT)	3.74	22	(AS)-(AT)	3.74
5	(ES)-(AE)	2	23	(AS)-(AE)	2
6	(ES)-(AE-S)	0	24	(AS)-(AE-S)	0
7	(ES)-(AE-T)	2	25	(AS)-(AE-T)	2
8	(ES)-(AE-E)	1.41	26	(AS)-(AE-E)	1.41
9	(ET)-(EE)	1.41	27	(AT)-(AE)	2.45
10	(ET)-(AS)	1.41	28	(AT)-(AE-S)	3.74
11	(ET)-(AT)	2.83	29	(AT)-(AE-T)	2.45
12	(ET)-(AE)	1.41	30	(AT)-(AE-E)	2.83
13	(ET)-(AE-S)	1.41	31	(AE)-(AE-S)	2
14	(ET)-(AE-T)	1.41	32	(AE)-(AE-T)	0
15	(ET)-(AE-E)	0	33	(AE)-(AE-E)	1.41
16	(EE)-(AS)	0	34	(AE-S)-(AE-T)	2
17	(EE)-(AT)	3.74	35	(AE-S)-(AE-E)	1.41
18	(EE)-(AE)	2	36	(AE-T)-(AE-E)	1.41

In this approach, however calculated distance is less shows that the two techniques is more similarity. By examining the calculations presented in Table (6) the following conclusions can be achieved:

- ✓ The results in the third and sixth and twenty-fourth rows of Table 6 shows the relative stability SAW technique is high in results ,this means that the results of this technique is not sensitive to the weighting.

- ✓ The results in the eleventh, fourteenth and twenty-ninth rows of Table 6 shows the results of TOPSIS technique is not very stable, this means that the results of this technique is very sensitive to the weighting

- ✓ The results in the Eighteenth, twenty-first and thirty-third rows of Table 6 shows the results of ELECTRE technique is not very stable, this means that the results of this technique is very sensitive to the weighting

- ✓ The results in the fourth row, seventh and twenty-eighth of the table (6) are made with the highest values shows the results of the use of various methods of weighting and decision-making can be very different. Therefore, it is necessary to make decisions with respect to the desired characteristics, the most consistent way to make decisions and choices weighting

4-2-2- Spearman's rank correlation coefficient

The basis for this approach is the use of Spearman's correlation coefficient to calculate the ranking of each pair of priority, the amount of the difference (di) is calculated and the correlation of equation (2) mentioned previously can be calculated. As correlation coefficient is higher, the difference between the two compounds together less. Table 7 shows the results of this approach.

Table 7. Spearman correlation coefficient values for the combination of different methods.

Row	Techniques compared	Euclidean distance	Row	Techniques compared	Euclidean distance
1	(ES)-(ET)	0.8	19	(EE)-(AE-S)	1
2	(ES)-(EE)	1	20	(EE)-(AE-T)	0.6
3	(ES)-(AS)	1	21	(EE)-(AE-E)	0.8
4	(ES)-(AT)	-0.4	22	(AS)-(AT)	-0.4
5	(ES)-(AE)	0.6	23	(AS)-(AE)	0.6
6	(ES)-(AE-S)	1	24	(AS)-(AE-S)	1
7	(ES)-(AE-T)	0.6	25	(AS)-(AE-T)	0.6
8	(ES)-(AE-E)	0.8	26	(AS)-(AE-E)	0.8
9	(ET)-(EE)	0.8	27	(AT)-(AE)	0.4
10	(ET)-(AS)	0.8	28	(AT)-(AE-S)	-0.4
11	(ET)-(AT)	0.2	29	(AT)-(AE-T)	0.4
12	(ET)-(AE)	0.8	30	(AT)-(AE-E)	0.2
13	(ET)-(AE-S)	0.8	31	(AE)-(AE-S)	0.6
14	(ET)-(AE-T)	0.8	32	(AE)-(AE-T)	1
15	(ET)-(AE-E)	1	33	(AE)-(AE-E)	0.8
16	(EE)-(AS)	1	34	(AE-S)-(AE-T)	0.6
17	(EE)-(AT)	-0.4	35	(AE-S)-(AE-E)	0.8
18	(EE)-(AE)	0.6	36	(AE-T)-(AE-E)	0.8

According to the results, it can be concluded that:

- ✓ According to the results of this approach, the technique SAW stability is high in the results (with the consideration of the third row, sixth and twenty-fourth of the table (7)) While stability results in TOPSIS and ELECTRE techniques .owis l(According to the eleventh row, fourteenth and twenty-ninth of the table (7) for TOPSIS technique and the fourth row, seventh and twenty-eighth of the table (7) for the technique ELECTRE).
- ✓ The results of the sixth row, eighth, thirteenth, fourteenth, fifteenth, nineteenth and twenty-first table (7) shows that using different techniques of decision-making in two ways weighting E, AE, correlation coefficients the upper is made this means that the two methods of weighting As mentioned previously, the correlation is very high.
- ✓ The results of the two methods of SAW and ELECTRE,in different weighting methods are relatively good correlation, in other words, the results of the two methods are similar

However, the correlation of results of ELECTRE and TOPSIS techniques is low as in the case of SAW and TOPSIS technique is also accept this.

5. CONCLUSION

According to the approach adopted for the evaluation of the resulting rankings, here are some tips to be provided as results:

- ➢ Entropy and AHP techniques to calculate weights of assessment indicators used are not correlated .in other words, the results of these two techniques are great differences, for this reason, the decision-maker, the proceeding is to choose one of these two techniques
- ➢ relation to the combined results of the two techniques(entropy and AHP) is not appropriate because the results of the equation very high correlation with the results of entropy techniques While the correlation of this results with the results of the AHP technique is much lower In other words, the relationship in such a way that the most effective

combination of these two methods will lead to the entropy techniques. This technique only on the basis of numerical analysis and engineering judgment in its impact is diluted.

- By examining the results of entropy techniques for weight indicator and comparison with the reality and the views of experts, concluded that the results of this approach that is based only on numerical analysis data is not very stable, in other words, this algorithm will be determined by considering the philosophy that index weights in this way, large or small as exaggerated obtained .For example, the calculated weight to the importance of ease of access and use of this technique is equal to 0.003 (close to zero), while the weight is 0.269 earmarked for noise pollution (maximum weight among the available weights), The numbers obtained by the views of experts, many differences, Thus, according to the explanations provided entropy techniques to determine the assessment index is not recommended
- SAW technique has a high relative stability in results this means that the results of these techniques are not very sensitive to the weighting And while conditions for the other two techniques (TOPSIS and ELECTRE) is quite different in other words, the results of these two techniques are very sensitive to the weighting method.
- high correlation between the results of two techniques for SAW and TOPSIS, in various ways weighting suggests that the results of the two methods is a lot of similarity , While the similarities in comparison SAW techniques and ELECTRE, ELECTRE and TOPSIS as seen below.
- Certain pattern that can be based on a weighting technique and a very high priority technical knowledge does not exist and selection of appropriate techniques for each question is based on personal experience researcher. Therefore, finding a significant relationship between the structure and the proper techniques, a separate investigation is required.

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