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Multicriteria Decision Analysis of Health Insurance for Foreigners in the Czech Republic

Haochen Guo

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Abstract

Multicriteria decision making (MCDM) is the superclass of model in most readily understandable branch of basic leadership. It is a branch of a general class of operations research (OR) models which manages choice issues under the nearness of various choice criteria. MCDM techniques have advanced to oblige different sorts of utilizations. Many techniques have been produced, with even small varieties to existing strategies bringing about the production of new branches of examination. The aim of this chapter is to present selected MCDM methods and application in case of health insurance decision problems.

Keywords: multicriteria decision making, SAATY method, WSA method, MAPPAC method, TOPSIS method, ELECTRE method, health insurance

1. Introduction

Multicriteria decision making (MCDM) has seen a staggering measure of utilization. Its part in various application territories has expanded fundamentally, particularly as new techniques are created and as old strategies make strides. This chapter breaks down a few basic MCDM strategies and decides their relevance by assessing their relative points of interest and burdens. A survey of the utilization of these strategies and an examination of the development of their utilization after some time is then performed. The objective of this chapter is through setting up a situation as case study which uses the MCDM methods (WSA, MAPPAC, TOPSIS, and ELECTRE) to choose the best and most appropriate health insurance (UNIQA, SLAVIA, MAXIMA, and VZP) for international policyholder visiting the Czech Republic.

2. Applications of MCDM approaches in decision problems

MCDM is a branch of a general class of operations research (OR) models which deals with decision problems under the presence of a number of decision criteria. In light of the distinctive purposes and diverse information sorts, MCDM is isolated into multiobjective decision making (MODM) and multiattribute decision making (MADM). Within the field of OR, the development of MCDM is based on the simple finding in terms of environment: criteria, goals, attributes, objectives, and decision matrix.

The MCDM field is given to the advancement of suitable procedures that can be utilized in circumstances where different clashing choice elements must be considered all the while.

Customary enhancement, measurable, and econometric investigation approaches utilized inside the money-related building connections regularly taking into account the presumption that the considered issue is all around postured, very much defined with respect to the truth included, and they as a rule consider the presence of a solitary target, assessment standard, or perspective that underlies the led examination. In such a case, the arrangement of monetary issues is anything but difficult to acquire. In any case, in reality, the demonstrating of monetary issues depends on an alternate sort of rationale mulling over the accompanying components:

• The presence of various criteria

• The clashing circumstance between the criteria

• The mind boggling, subjective, and not well-organized nature of the assessment process

• The presentation of money-related chiefs in the assessment process

Financial related and operation specialists have as of late embraced this creative, thorough, and reasonable point of view, with results. On the premise of the diverse creators' view that it is conceivable to recognize primary reasons which have persuaded a change of perspective in the displaying of the money-related issues:

• Formulating the issue as far as looking for the ideal, objective get included in an exceptionally limit dangerous, regularly unessential to the genuine choice issue.

• The diverse monetary choices are taken by the people and not by the models; the leaders get increasingly profoundly included in the basic leadership process. With a specific end goal to take care of issues, it gets to be important to think about their inclinations, their encounters, and learning.

• For monetary choice issues, for example, the decision of venture undertakings, the portfolio choice, and the assessment of business disappointment hazard.

MCDM methodologies are appropriate for the investigation of a few money-related basic leadership issues. The broadened way of the components that influence monetary choices, the many-sided quality of the money related, business and financial situations, the subjective way of numerous budgetary choices are just a percentage of the elements of money-related choices which are as per the MCDM demonstrating system. **Table 1** outlines the utilizations of MCDM techniques.

Method	Advantages	Disadvantages	Areas of application
MAUT	Takes uncertainty into account; can incorporate preferences	Needs a lot of input; preferences need to be precise	Economics, finance, actuarial, water management, energy management, agriculture
AHP	Easy to use; scalable; hierarchy structure can easily adjust to fit many sized problems; not data intensive	Problems due to interdependence between criteria and alternatives; can lead to inconsistencies between judgment and ranking criteria; rank reversal	Performance-type problems, resource management, corporate policy and strategy, public policy, political strategy, and planning
CBR	Not data intensive; requires little maintenance; can improve over time; can adapt to changes in environment	Sensitive to inconsistent data; requires many cases	Businesses, vehicle insurance, medicine, and engineering design
DEA	Capable of handling multiple inputs and outputs; efficiency can be analyzed and quantified	Does not deal with imprecise data; assumes that all input and output are exactly known	Economics, medicine, utilities, road safety, agriculture, retail, and business problems
Fuzzy set theory	Allows for imprecise input; takes into account insufficient information	Difficult to develop; can require numerous simulations before use	Engineering, economics, environmental, social, medical, and management
SMART	Simple; allows for any type of weight assignment technique; less effort by decision makers	Procedure may not be convenient considering the framework	Environmental, construction, transportation and logistics, military, manufacturing and assembly problems
GP	Capable of handling large-scale problems; can produce infinite alternatives	It's ability to weight coefficients; typically needs to be used in combination with other MCDM methods to weight coefficients	Production planning, scheduling, health care, portfolio selection, distribution systems, energy planning, water reservoir management, scheduling, wildlife management
ELECTRE	Takes uncertainty and vagueness into account	Its process and outcome can be difficult to explain in layman's terms; outranking causes the strengths and weaknesses of the alternatives to not be directly identified	Energy, economics, environmental, water management, and transportation problems
PROMETHEE	Easy to use; does not require assumption that criteria are proportionate	Does not provide a clear method by which to assign weights	Environmental, hydrology, water management, business and finance, chemistry, logistics and transportation, manufacturing and assembly, energy, agriculture
SAW	Ability to compensate among criteria; intuitive to decision makers; calculation is simple does not require complex computer programs	Estimates revealed do not always reflect the real situation; result obtained may not be logical	Water management, business, and financial management
TOPSIS	Has a simple process; easy to use and program; the number of steps remains the same regardless of the number of attributes	Its use of Euclidean distance does not consider the correlation of attributes; difficult to weight and keep consistency of judgment	Supply chain management and logistics, engineering, manufacturing systems, business and marketing, environmental, human resources, and water resources management

Source: See Mark and Patrick (2013).

Table 1. Summary of MCDM methods.

3. Case study: MCDM of health insurance products in the Czech Republic

Everybody who visits the Czech Republic needs sufficient proof of health insurance. If you are a nonEU national and do not work for a Czech employer, you need to get travel health insurance before coming to the Czech Republic. Based on this background, the subject of the case study is an international tourist who wants to visit the Czech Republic and hence needs to make a decision for health insurance.

3.1. Health insurance for foreigners in the Czech Republic

Foreign nationals in the Czech Republic are required to have valid health insurance. There are two types of health insurance that are described below:

1. **Public health insurance**

   The following people have a legal right to public health insurance:

   • Anyone with permanent residency status in the Czech Republic

   • Employees whose employer is based in the Czech Republic

2. **Commercial (private) health insurance**

   There are two varieties of commercial health insurance:

   • Comprehensive medical insurance: it is suitable for foreigners who intend to stay for 90 days or longer and require long-term visa or long-term stay, or request an extension of a visa or residence permit. This health insurance is similar to public health insurance.

   • Basic medical insurance: it covers necessary treatment and hospitalization which cannot be postponed at all health care facilities. This insurance is recommended for individuals who do not fall under the public health system and plan only short-term stay. The insurance covers costs incurred as a result of an accident or sudden illness during the stay, including any costs related to repatriation to the country that issued the travel document or to the country where the foreigner has legal residence. Minimal coverage must be EUR 60,000 excluding any financial contribution to the aforesaid costs on the part of the insured person. See euraxess.cz.

3.2. Input data interpretation – weight calculation criteria (SAATY method)

Usually, before selecting the best and most appropriate health insurance, policyholder needs to consider the items of premium, claims, and minimum coverage maturity as criteria. Also, there are four insurance companies who provide health insurance for foreigner as alternatives, which are Pojišťovna VZP, a.s., UNIQA pojišťovna, a.s., MAXIMA pojišťovna, a.s., and SLAIA pojišťovna (see **Table 2**).

		C1	C2	C3
		Premium/CZK per month	Claims/CZK per month	Min. coverage maturity/month
A1	UNIQA	550	2,026,852	3
A2	SLAVIA	433	1,000,000	3
A3	MAXIMA	635	1,621,482	6
A4	VZP	1235	3,000,000	4
		MIN	MAX	MIN

Source: pojistenicizincu.cz.

Table 2. Input data.

In the process of making multiattribute decision, it should set weight for different criteria by using direct and indirect method, and in this case study will use the SAATY pairwise comparison method (Thomas, 2004, 2006, 2008),which is a kind of indirect method created by Thomas L. Saaty. **Table 3** presents a typical criteria matrix C.

	C1	C2	C3	C4
C1	C11	C12	C13	C14
C2	C21	C22	C23	C24
C3	C31	C32	C33	C34
C4	C41	C42	C43	C44

Table 3. Typical criteria matrix C.

$C_{i,j}$ in **Table 3** presents the preference on criteria i to criteria j. Which is also called the ratio w_i/w_j, and the preference can be judged from 1 to 9 in fundamental scale of absolute number which will be shown in **Table 4**, $C_{i,j} \in [\frac{1}{9}, 9]$ and $C_{i,j} \cdot C_{j,i} = 1$. Hence, if preferred i to j, then $C_{i,j} > 1$; if preferred j to i, then $C_{i,j} < 1$; if preferred the same preference on criteria i to j, then $C_{i,j} = 1$.

Table 5 provides the weights calculated by the SAATY method.

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
2	Week or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrate importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
1.1–1.9	When activities are very close a decimal is added to 1 to show their difference as appropriate	A better alternative way to assigning the small decimals is to compare two close activities with other widely contrasting ones, favoring the larger one a little over the smaller one when using the 1–9 values
Reciprocals of above	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	A logical assumption
Measurements from ratio scales		When it is desired to use such numbers in physical applications. Alternatively, often one estimates the ratios of such magnitudes by using judgment

Source: See Thomas (2008).

Table 4. Fundamental scale of absolute numbers.

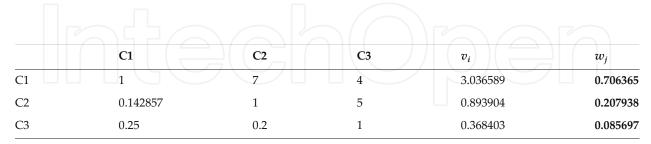|	C1	C2	C3	v_i	w_j
C1	1	7	4	3.036589	**0.706365**
C2	0.142857	1	5	0.893904	**0.207938**
C3	0.25	0.2	1	0.368403	**0.085697**

Table 5. Weights calculate by SAATY method.

4. Results due to select methods

In this section, the procedure for four MCDM methods, which are WSA, MAPPAC, TOPSIS, and ELECTRE III, will be demonstrated.

4.1. WSA method

Weighted sum analysis method is based on the linear utility function construction at the scale 0–1. The worst variant based on the given criteria will have utility 0; the best variant will have utility 1 and other variants will have utility between both extreme values. WSA derives from the principle of utility maximization; however, the method presumes only linear function. For the maximization case, the best alternative is the one that yields the maximum total performance value.

First, the normalized criteria matrix will be created $R = (r_{ij})$, whose elements are derived from criteria matrix $Y = (y_{ij})$, based on

$$r_{ij} = \frac{Y_{ij} - D_j}{H_j - D_j},$$
(1)

where r_{ij} is variant's utility of X_i when evaluated based on criteria Y_j, r_{ij} represents corresponding values from initial criteria matrix, D_j is the lowest criteria value of Y_j, and H_j is the highest criteria value of Y_j. This matrix represents matrix of utility values from ith variant based on jth criteria. Criteria values are linearly transformed that $r_{ij} \in \langle 0, 1 \rangle$. D_j corresponds to minimal criteria value of column j and H_j corresponds to maximum criteria value in column j. In case of minimization criteria normalization of column in matrix can be executed as

$$r_{ij} = \frac{H_j - Y_{ij}}{H_j - D_j}.$$
(2)

If it is necessary that all criteria in the matrix must be maximized then before executing standardization/normalization of matrix, it is necessary to recount elements in the column as follows

$$Y_{ij-\max} = H_{j-\min} - Y_{ij-\min}, \ i = 1, 2, ..., p.$$
(3)

Meaning, deduct from the current highest element maximum $H_{j-\min}$ in the given column progressively with all other elements and by this the column with minimization criteria will be transformed to maximization. When using additive multicriterial utility function the variance utility a_i is then equal to

$$u(a_i) = \sum_{j=1}^{k} v_j \cdot r_{ij}.$$
(4)

Variant that reaches the maximum utility value is selected as the best, alternatively it is possible to rank the variants based on descending utility values, see Iveta and Jana (2015). The calculation of WSA method is done by the following procedures.

Obtaining the utilities and the preferred order of alternatives can be expressed as: A1 > A2 > A3 > A4. Hence, on the basis of the results above, the optimal choice is: UNIQA > SLAVIA > MAXIMA > VZP.

4.2. MAPPAC method

Multicriterion analysis of preferences by means of pairwise actions and criterion comparisons (MAPPAC) method, first introduced by Matarazzo (1986), is based on the comparison of pairs of feasible actions taking into account all possible pairs of criteria. The proposed method, known as MAPPAC, is based on a pairwise comparison of alternatives relative to each pair of criteria, defining the two relations P (preference) and I (indifference), which constitute a complete preorder. Moreover, by aggregating these preferences, it is possible to obtain a variety of relations on a set of feasible actions (Paruccini and Matarazzo, 1994). See Salt (2011).

The MAPPAC method has three assumptions (Matarazzo, 1990):

- For each K_i a quantitative, V_{ij} can be assigned to each alternative, a_j representing the performance of a_j with respect to K_i;

- A quantitative value $V_{ij}c$;

- An be assigned to each alternative, a_j on the basis of each criterion K_i;

- The value $V(V_{ij})$ of each V_{ij} can be quantified on the interval [0,1]; and

- The criteria are mutually difference and independent.

For each K_i a value V_{ij} is assigned to each a_j representing the performance of a_j on the basis of K_i. A numerical weight w_i is assigned to each K_i representing the importance of K_i with $\sum_{n=1}^{n} w_i = 1$. For each K_i representing the importance of $v(v_{ij})$ to each V_{ij} with $0 \leq v(v_{ij}) \leq 1$. see Hassan (2013). The calculation of MAPPAC method is done by the following procedures. The process of modified input data is the same in **Table 6**.

	MAX	MAX	MAX
	C1	C2	C3
A1	685	2,026,852	3
A2	802	1,000,000	3
A3	600	1,621,482	0
A4	0	3,000,000	2
Weights	0.70636	0.20794	0.08570

Table 6. WSA modified input data.

Obtaining the utilities and the preferred order of alternatives can be expressed as: A2 > A1 > A3 > A4. Hence, on the basis of the results above, the optimal choice is: SLAVIA > UNIQA > MAXIMA > VZP (**Tables 7–9**).

	MAX	MAX	MAX	
	C1	C2	C3	U (alternatives)
A1	0.85411	0.51343	1.00000	**0.79577**
A2	1.00000	0.00000	1.00000	**0.79206**
A3	0.74813	0.31074	0.00000	**0.59307**
A4	0.00000	1.00000	0.66667	**0.26507**
Weights	0.70636	0.20794	0.08570	

Table 7. WSA normalized criterion matrix R.

	C1	C2	C3
A1	0.85411	0.51343	1.00000
A2	1.00000	0.00000	1.00000
A3	0.74813	0.31074	0.00000
A4	0.00000	1.00000	0.66667
Weights	0.70636	0.20794	0.08570

Table 8. MAPPAC matrix C.

	A1	A2	A3	A4	From above	Total
A1	0.00000	0.37944	1.00000	0.81985	2	**2**
A2	0.62056	0.00000	0.81509	0.76695	1	**1**
A3	0.00000	0.18491	0.00000	0.71701	3	**3**
A4	0.18015	0.23305	0.28299	0.00000	4	**4**
From below	2	1	3	4		

Table 9. MAPPAC matrix P.

4.3. TOPSIS method

The technique for order of preference by similarity to ideal solution (TOPSIS) is based on the concept that the chosen alternative should have the shortest distance from the positive ideal solution and the longest distance from the negative ideal solution. It is a method of compensatory aggregation that compares a set of alternatives by identifying weights for each criterion, normalizing scores for each criterion and calculating the distance between each alternative and the ideal alternative, which is the best score in each criterion. The TOPSIS method is expressed in a succession of six steps as follows:

1. Calculate the normalized decision matrix. The normalized value r_{ij} is calculated by

$$r_{ij} = x_{ij}\sqrt{\sum_{i-1}^{m}x_{ij}^2}\ i = 1, 2, ..., m \ \text{ and } j = 1, 2, ..., n. \tag{5}$$

2. Calculate the weighted normalized decision matrix

$$v_{ij} = r_{ij}\, w_j\ i = 1, 2, ..., m \text{ and } j = 1, 2, ..., n. \tag{6}$$

where w_j is the weight of the jth criterion or attribute and $\sum_{j=1}^{n}w_j = 1$.

3. Determine the ideal (A^*) and negative ideal (A^-) solutions

$$A^* = \{(\max_i v_{ij}|j\in C_b), (\min_i v_{ij}|j\in C_c)\} = \{v_j^*|j = 1, 2, ..., m\} \tag{7}$$

$$A^- = \{(\min_i v_{ij}|j\in C_b), (\max_i v_{ij}|j\in C_c)\} = \{v_j^-|j = 1, 2, ..., m\} \tag{8}$$

4. Calculate the separation measures using the m-dimensional Euclidean distance. The separation measures of each alternative from the positive ideal solution and the negative ideal solution, respectively, are as follows

$$S_i^* = \sqrt{\sum_{j=1}^{m}(v_{ij}-v_j^*)^2}, j = 1, 2, ..., m \tag{9}$$

$$S_i^- = \sqrt{\sum_{j=1}^{m}(v_{ij}-v_j^-)^2}, j = 1, 2, ..., m \tag{10}$$

5. Calculate the relative closeness to the ideal solution

$$RC_i^* = \frac{S_i^-}{S_i^* + S_i^-}, i = 1, 2, ..., m \tag{11}$$

6. Rank the preference order.

The calculation of TOPSIS method is done by the following procedures (**Tables 10** and **11**).

	MIN	MAX	MIN
	C1	C2	C3
A1	0.35367	0.49543	0.35857
A2	0.27843	0.24443	0.35857
A3	0.40833	0.39634	0.71714
A4	0.79414	0.73329	0.47809
Weights	0.70636	0.20794	0.08570

Table 10. TOPSIS normalized matrix R.

	MIN	MAX	MIN			
	C1	C2	C3	di+	di-	ci
A1	0.24982	0.10302	0.03073	0.07260	0.31698	**0.81365**
A2	0.19668	0.05083	0.03073	0.10165	0.36557	**0.78243**
A3	0.28843	0.08241	0.06146	0.11946	0.27435	**0.69665**
A4	0.56096	0.15248	0.04097	0.36442	0.10370	**0.22152**
Weights	0.70636	0.20794	0.08570			
Ideal	0.19668	0.15248	0.03073			
Basal	0.56096	0.05083	0.06146			

Table 11. TOPSIS weighted criterion matrix W.

Obtaining the utilities and the preferred order of alternatives can be expressed as: A1 > A2 > A3 > A4. Hence, on the basis of the results above, the optimal choice is: UNIQA > SLAVIA > MAXIMA > VZP.

4.4. ELECTRE III method

The ELECTRE (for elimination and choice translating reality; English translation from the French original) method was first introduced in Benayoun et al. (1966). The basic concept of the ELECTRE method is to deal with "outranking relations" by using pairwise comparisons among alternatives under each one of the criteria separately. The outranking relationship of the two alternatives A_i and A_j denoted describes that even when the ith alternative does not dominate the jth alternative quantitatively, then the decision maker may still take the risk of regarding A_i as almost surely better than A_j in Roy (1973). Alternatives are said to be dominated, if there is another alternative which excels them in one or more criteria and equals in the remaining criteria.

The ELECTRE method begins with pairwise comparisons of alternatives under each criterion. Using physical or monetary values, denoted as $g_i(A_j)$ and $g_i(A_k)$ of the alternatives A_j and A_k, respectively, and by introducing threshold levels for the difference $g_i(A_j)-g_i(A_k)$, the decision maker may declare that he/she is indifferent between the alternatives under consideration, that he/she has a weak or a strict preference for one of the two, or that he/she is unable to express any of these preference relations. Therefore, a set of binary relations of alternatives, the so-called outranking relations, may be complete or incomplete. Next, the decision maker is requested to assign weights or importance factors to the criteria in order to express their relative importance.

Through the consecutive assessments of the outranking relations of the alternatives, the ELECTRE method elicits the so-called concordance index, defined as the amount of evidence to support the conclusion that alternative A_j outranks, or dominates, alternative A_k, as well as the discordance index, the counterpart of the concordance index. Finally, the ELECTRE method yields a system of binary outranking relations between the alternatives (**Tables 12** and **13**).

	A1	A2	A3	A4
A1	0.00000	0.20794	1.00000	0.79206
A2	0.70636	0.00000	0.79206	0.79206
A3	0.00000	0.20794	0.00000	0.70636
A4	0.20794	0.20794	0.29364	0.00000

Table 12. ELECTRE III matrix S.

Indifference classes	Alternatives
1.	UNIQA
2.	SLAVIA
3.	MAXIMA
4.	VZP

Table 13. ELECTRE III indifference classes.

The calculation of ELECTRE method is done by the following procedures. The first process of modified input data is the same in **Table 6**.

Obtaining the utilities and the preferred order of alternatives can be expressed as: A1 > A2 > A3 > A4. Hence, on the basis of the results above, the optimal choice is: UNIQA > SLAVIA > MAXIMA > VZP.

5. Discussion and summary

Using the Borda method to rank the results obtains the most appropriate insurance for policyholder. The Borda method is an election method in which the voters rank options or candidates in order of preference: the highest Borda count wins.

Table 14 presents the Borda method result for optimal health insurance.

Based on the Borda method result, UNIQA wins with highest Borda count, hence the optimal health insurance for policyholder is UNIQA.

	WSA	MAPPAC	TOPSIS	ELECTRE	SUM	Ranking
UNIQA	1	2	1	1	5	1
SLAVIA	2	1	2	2	7	2
MAXIMA	3	3	3	3	12	3
VZP	4	4	4	4	16	4

Table 14. Borda method for optimal health insurance.

6. Conclusion

Various MCDM techniques have been developed and used in the course of recent years. As of late, on account of easement cause by driving development, consolidating diverse techniques has ended up ordinary in MCDM. The blend of numerous techniques addresses gaps that might be found in specific strategies. These strategies, alongside the techniques in their unique structures, can be to a great degree fruitful in their applications, just if their qualities and shortcomings are appropriately surveyed. This chapter illustrates the case study of MCDM methods and evaluation for solving the problem which select the optimal choice of health insurance for foreigners who are willing to visit the Czech Republic.

Acknowledgements

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