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The Role of Decision Optimization in Urban Transport Management

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A R T I C L E   I N F O

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A B S T R A C T

Multi-criteria decisions play a defining role in the management processes of any organization. In transport, conflicting criteria are frequently encountered in the evaluation of decision options, such as cost and quality. Techniques to optimize multi-criteria decisions can be applied in various situations, e.g., fleet vehicle procurement. Managers usually evaluate implicit criteria, but decision-making processes with major implications require an explicit and structured evaluation of several criteria. The application of multi-criteria decision optimization techniques leads to informed, optimized decisions and thus to risk reduction and resource savings. In practice, multi-criteria decision optimization techniques are mathematically modelled to achieve better accuracy. The analysis of multi-criteria decision optimization techniques involves objectives, preferences, evaluation criteria, decision alternatives, uncontrollable variables, and consequences. In this study, a decision optimization application made in Microsoft Excel and an application designed in Python that can assist managers of urban transport companies in the decision of choosing the most suitable vehicles for their fleet are presented.

1. Introduction

Multi-criteria decision-making is a sub-discipline of operations research that explicitly evaluates multiple conflicting criteria in decision-making (in everyday life and in business, government, and medicine). Conflicting criteria are typical in option evaluation: cost or price are among the main criteria, and a measure of quality is usually another criterion in conflict with cost. In buying a car, for example, cost, comfort, safety, and fuel economy may be some of the main criteria we consider. It is unusual for the cheapest car to be the most comfortable and the safest. In managing our stock market investment portfolio, we are interested in making high returns while reducing our risks, but stocks that have the potential to bring high returns also carry high risks of losing money. In a service industry, customer satisfaction and the cost-of-service delivery are fundamental conflicting criteria.

In the usual management processes, decisions are analyzed in terms of several criteria that give managers a certain comfort about the consequences of such decisions based on intuition alone. At the same time, when the stakes are high, it is important to structure the problem correctly and explicitly evaluate several criteria. When making the decision to purchase new buses and where they can be purchased from, there are not only very complex issues involving multiple criteria but there are also multiple parties that are affected by the consequences.

Complex structuring of decision-making issues and consideration of multiple criteria explicitly leads to better and more informed decisions, reduced risks, and resource savings (Munteanu, A. I., Bibu, N., Nastase, M., Cristache, N., & Matis, C., 2020). Significant progress has been made in this area since the beginning of the modern discipline of multi-criteria decision-making techniques.

2. Literature review

Decision-making is a problem encountered by every entity in their daily activities (Dobre, I., Bădescu, A.V., Păuna, L, 2007). It often involves an evaluation that entails working with a considerable amount of information, which is difficult if the information is not properly structured. At the same time, a wide range of criteria covering different aspects must be taken into account, which may lead to conflicting situations. Although it is believed that having as much information as possible clarifies the issues, processing it is more complicated as the number of conflicting criteria increases. Therefore, making a decision (Grigorescu, C.J.,

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Ghic, G, 2014), in a complex situation, is less about identifying an optimal solution and more about an optimal compromise. At the same time, it results in prioritizing options, eliminating unacceptable options, and selecting a limited number of options for further detailing (Cristache, N. et al., 2019).

Such an analysis is subject to a high degree of subjectivity and, therefore, in order to achieve the best possible accuracy, a mathematical model is created. However, there are certain unmeasurable criteria, for whose integration in the mathematical process, an unconventional system of measurement is applied.

In general, multicriteria decision analysis (abbreviated MCDA) involves 6 components (Peterson, M., 2019):

- the objectives the decision-maker wants to achieve;
- the decision-maker's preferences regarding the evaluation criteria;
- evaluation criteria (objectives and/or physical attributes);
- alternative decisions;
- the uncontrollable variables of the states of nature;
- the consequences associated with each pair of alternative attributes.

There are several approaches within the MCDA that differ in the way information is managed. They can be classified into three categories, depending on the major components of multi-criteria decision analysis (Grigorescu, C. J., Ghic, G., 2014): multi-objective/multi-attributive decision, individual/collective decision, and decision under certainty/uncertainty conditions.

Multi-attribute decision problems entail that choices are among the alternatives described by their attributes. The set of attributes is given explicitly, and this type of problem has a finite number of feasible alternatives. In contrast, multi-objective decision problems involve searching for the best solution among an infinite or very large number of alternatives (Gabor, M. R., Kardos, M., Cristache, N., Nastase, M., & Petrariu, I. R., 2021). Each alternative is evaluated using objective functions.

The classification of decision issues into individual and collective does not depend on the number of decision-makers but on the hierarchy of objectives. If there is a single hierarchy, applicable to the whole group, then the problem is reduced to one of individual decision-making. If, however, differences in preferences arise, the problem becomes one of collective decision (Yu, P.L., 2019).

The other classification depends on knowledge of the evolution of external factors. If the decision-maker has sufficient information about this, then the decision problem is in a state of certainty. In real cases, however, there are some unpredictable or difficult-to-predict aspects that lead to uncertainty.

Steps to solve a multi-criteria decision problem

The steps to solve a multi-criteria decision problem are:

1. identifying the problem or opportunity for change;
2. determining alternatives;
3. choosing the best alternative.

The problem is revealed by the decision-maker's analysis of the discrepancy between goals and reality. This stage is only found at the conceptual level, as the decision-maker analyses the preliminary data of the problem.

Setting criteria and priorities is the next step. The superiority in the importance of one criterion over another is dictated by the nature of the objectives pursued and leads to a more concise formulation of the problem, eliminating unacceptable alternatives. Prioritizing the criteria not only narrows down the alternatives but also increases the complexity of the problem.

3. Research methodology

This paper aims to highlight how there was an European and international trend of In this paper, we aim to analyze decision optimization techniques in the context of the existence of certainties. Thus, it is very important to establish the nature of the variables involved, i.e., the state of the objective conditions that mark the problem to be subjected to decisional resolution (Parmigiani, G., Inoue, L., 2019). The following methods belong to this category:

- Simple Additive Weighting (SAW);
- Elimination Et Choix Traduisant la Réalité (ELECTRE) (two-and three-dimensional);
- The Onicescu method (decision table).

The SAW method involves the following steps:

1) setting the decision-making context, the decision-making problem, its objectives, and the decision-maker. Basically, in the first phase, the decision-maker states the problem s/he wants to solve and outlines the objectives s/he wants to achieve or the parameters s/he will take into account to determine the optimal response.
2) determination of the attributes to be taken into account;
3) determination of the importance of criteria/attributes;
4) assignment of evaluation weights to the criteria set out above;

5) calculation of the score/priority of each criterion in the overall decision;
6) use of aggregation functions for the scores and weights of the criteria considered;
7) obtaining the final result.

The two-and three-dimensional ELECTRE method is a multi-criteria analysis method that consists of establishing a decision matrix containing information about decision alternatives and evaluation criteria. Based on this matrix, preference relationships between alternatives can be constructed and optimal solutions identified.

The steps of the ELECTRE I method are:

1) establishing decision alternatives and evaluation criteria;
2) defining a set of weights for each criterion reflecting its importance in the decision problem;
3) establishing a decision matrix containing the values of each criterion for each alternative;
4) calculating a concordance matrix and a discordance matrix showing to what extent one alternative meets the requirements of a criterion and to what extent it contradicts the others;
5) defining an acceptability threshold for alternatives and eliminating those that do not meet it;
6) calculating a preference matrix indicating the preference relationship between the remaining alternatives;
7) identifying the optimal solutions with the best positions in the preference matrix.

The three-dimensional ELECTRE method or ELECTRE III is a multi-criteria analysis method that consists in establishing a set of preference relations between decision alternatives according to three main criteria: concordance, discordance, and indifference (Grecu, L., 2015).

The steps of the ELECTRE III method are:

1) establishing decision alternatives and evaluation criteria;
2) defining a set of weights for each criterion reflecting its importance in the decision problem;
3) establishing a decision matrix containing the values of each criterion for each alternative;
4) calculating a concordance matrix and a discordance matrix showing to what extent one alternative meets the requirements of a criterion and to what extent it contradicts the others;
5) setting a set of acceptability thresholds for concordance and discordance, as well as for the criterion of indifference, representing a minimum level of satisfaction for each criterion;
6) calculating a set of preference indices reflecting the preference relationship between alternatives, according to concordance, discordance, and indifference;
7) identifying the optimal solutions which are the best ranked in the preference matrix.

The ELECTRE III method is an extension of the ELECTRE I method, adding a third evaluation criterion, indifference, which allows the assessment of the degree of indifference between decision alternatives. The acceptability thresholds for agreement and disagreement are defined to reflect the minimum level of satisfaction for each criterion. The preference matrix is calculated to reflect the preference relationship between the decision alternatives according to all three criteria. Thus, ELECTRE III can provide a more complex and accurate solution to multi-factor decision problems compared to ELECTRE I.

The Onicescu method aims to solve complex decision problems by means of specific algorithms based on mathematical logic. These algorithms have the great advantage of eliminating the complicated and iterative mathematical calculations of the ELECTRE method.

Stages of the Onicescu method:

1) the set of decision options is identified

$$\mathbf{V} = \{\mathbf{V1}, \mathbf{V2}, \mathbf{V3}, \ldots\ \mathbf{Vi}\} \quad (1)$$

2) determine the criteria

$$C = \{C1, C2, C3, \ldots\ Cj\} \quad (2)$$

3) write the consequence matrix

$$A = \{a_{ij}\} = value\ \textbf{of the criterion j in variant} \quad (3)$$

4) maximum criteria are chosen, i.e., those for which the value of the beneficial decision consequence is the maximum;
5) the minimum criteria are selected, i.e., those for which the value of the most advantageous decision consequence is the minimum;
6) the variants for each criterion are ordered in descending order of consequences (for maximum criteria) and in ascending order of consequences (for minimum criteria), resulting in a new matrix, denoted by B;
7) write a new matrix C indicating how many times a variant i occupies the place j;

8) rank the variants according to an attenuation function (where the coefficients are taken from the matrix C)

$$f(V_i) = c_{i1}\frac{1}{2} + c_{i2}\frac{1}{2^2} + \cdots + c_{im}\frac{1}{2^m} \quad (4)$$

9) the optimal variant is the one that gives the maximum value of f.

Advantages and disadvantages of the methods and techniques used for optimizing decisions under certainty

The use of decision optimization methods and techniques under certainty can bring several advantages, including:

- solving the decision-making problem in a systematic way, based on objective data and information, which leads to better decisions;
- reducing the time and effort required to make a decision, as optimization methods can be used to reduce the number of decision alternatives that need to be considered;
- improving the quality of the decisions made, as optimization methods allow the identification of solutions that maximize or minimize a set of pre-defined criteria;
- the opportunity to test different scenarios and identify the best solution from a large number of decision alternatives;
- reducing subjectivity in the decision-making process, as optimization methods are based on predetermined calculations and criteria, thus eliminating the subjective influence of decision-makers;
- resource efficiency, as optimization methods can be used to identify the best solutions that optimize the use of available resources.
- improving communication and collaboration between decision-makers team members, as optimization methods allow the objective evaluation of decision alternatives, which can lead to reduced tensions and conflicts. (Afshari, A., Mojahed, M., Yusuff, R, 2010):

Decision optimization techniques and methods may have several drawbacks, including:

- complexity - some of these techniques and methods are very complex and require a deep understanding, as well as advanced mathematical and programming skills; this can make them difficult and expensive to use.
- criteria limitation - in order to be able to apply these techniques and methods, all decision factors must be known with certainty and be quantifiable in an objective way; if there are subjective or unknown factors, these techniques and methods cannot be used effectively.
- input data errors - inaccurate or incomplete input data can lead to errors in the decision optimization process and incorrect decision-making;
- time required - some of these techniques and methods may require a lot of time and resources to produce an optimal solution, which may be impractical in terms of time or cost.
- interpretation and application of results - another issue may be the correct interpretation and application of the results generated by these techniques and methods. Users may find it difficult to understand how these results should be applied in their specific situation (Kaliszewski, I., Podkopaev, D., 2013).

Implementation of multi-criteria decision optimization techniques

In this paper, in addition to presenting multi-criteria decision optimization methods, we have implemented the Simple Additive Weighting (SAW) decision optimization technique through two software applications: a decision optimization application developed in Microsoft Excel and an application designed in Python language that assists buyers of used car in the decision to choose the most suitable car.

A table (Figure 1) has been created in Microsoft Excel. The products or services to be evaluated can be entered together with their characteristics, which will be taken into account in making the optimal decision. Each criterion will be given a score according to each characteristic. Note that scores can be given automatically, if necessary, when characteristics are numerical values, but there are situations where these characteristics do not take numerical values and then the scores to be given according to the user's preferences need to be checked. Subsequently, each criterion will be given a weight taking into account the importance of each of these criteria for the end user.

	Pondere	0.1		0.1		0.3		0.3		0.2		
	Produs / Serviciu	Criteriu 1	Notă	Criteriu 2	Notă	Criteriu 3	Notă	Criteriu 4	Notă	Criteriu 5	Notă	Scor
1	1A	A	3	E	5	J	2	O	2	T	2	0.48
2	2B	B	5	F	2	K	1	P	2	U	3	0.44
3	3C	C	4	G	4	L	2	Q	2	V	5	0.6
4	4D	D	2	H	3	M	4	R	2	W	4	0.62
5	5E	E	1	I	1	N	5	S	5	X	1	0.68

Figure 1. SAW method implemented using Microsoft Excel

Source: author processing

Each score given to each criterion will be multiplied by the weight assigned to that criterion and added to the multiplication of the rest of the criteria and weights for a product, then divided by the maximum score given to the characteristics. The score obtained will be compared with the score obtained by the rest of the products and services, and the most optimal decision will be thus decided.

Formulas used in Microsoft Excel:

$$Product\_Service\ 1A = SUM\left(\frac{(D3*E5)+(F3*G5)+(H3*I5)+(J3*K5)+(L3*M5)}{5}\right) \quad (5)$$

$$Product\_Service\ 2B = SUM\left(\frac{(D3*E6)+(F3*G6)+(H3*I6)+(J3*K6)+(L3*M6)}{5}\right) \quad (6)$$

$$Product\_Service\ 3C = SUM\left(\frac{(D3*E7)+(F3*G7)+(H3*I7)+(J3*K7)+(L3*M7)}{5}\right) \quad (7)$$

$$Product\_Service\ 4D = SUM\left(\frac{(D3*E8)+(F3*G8)+(H3*I8)+(J3*K8)+(L3*M8)}{5}\right) \quad (8)$$

$$Product\_Service\ 5E = SUM\left(\frac{(D3*E9)+(F3*G9)+(H3*I9)+(J3*K9)+(L3*M9)}{5}\right) \quad (9)$$

Where, columns D3, F3, H3, J3 and L3 represent the weight given to the criteria and columns E, G, I, K and M represent the scores given to the criteria for each product or service.

The second software application by which we implement the SAW decision optimization method assists the user in deciding to purchase the most suitable used car based on the criteria selected by the user.

Information about cars and their characteristics is stored in a SQLITE database. It is queried via the computer application whose interface (Figure 2) allows the user to select the desired criteria. Thus, the car that meets the most criteria selected by the user is searched for and the answer is optimized by the Simple Additive Weighting method.

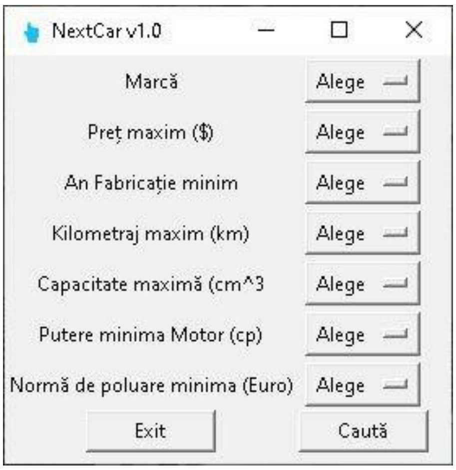

Figure 2. Application interface

Source: author processing

The weights for each criterion are assigned within the application by the programmer using the code sequence shown in Figure 3.

```
self.weights = {
    "Marca": 0.2,
    "Pret Maxim": 0.15,
    "An Fabricatie Minim": 0.15,
    "Kilometraj Maxim": 0.15,
    "Capacitate Maxima": 0.1,
    "Putere Motor Minima": 0.1,
    "Norma Poluare Minima": 0.05
}
```

Figure 3. Assignment of weights to each criterion

Source: author processing

As for the scores for each criterion (Figure 4), they are assigned by the application to each criterion of each car, depending on how close it is to the choice made by the user from the drop-down list within the graphic interface.

```
weights = {}
for criterion, value in criteria_values.items():
    criterion_data = self.data[criterion]
    if pd.api.types.is_numeric_dtype(criterion_data.dtype):
        criterion_value = float(value)
        max_value = criterion_data.max()
        distance = abs(criterion_data - criterion_value)
        note = np.maximum(0, 1 - distance / max_value)
    else:
        distance = criterion_data != value
        note = np.where(distance, 0, 1)
    weights[criterion] = note
```

Figure 4. Assignment of scores to each criterion of each car according to user requirements

Source: author processing

After the scores have been assigned, the software application calculates the score for each car by summing the weighted values of the criteria and displays the answer if it can be found in the database. If a car that is close to the user's requirements cannot be found, the application displays a message telling the user that the selection has not returned a suitable answer and asking the user to modify the characteristics of the desired machine.

Possible improvements to the software product could be:

- modification of the user interface to make it easier to use and interpret by users;
- giving the user the possibility to manually select, from the interface of the application, which criteria should weigh higher and which should have a lower weight in the decision-making process;
- the possibility to issue a report from the application so that the user can keep it and use it later if needed;
- integrating several methods and techniques to further optimize the final decision;
- retrieving products/services and their characteristics directly from a database so that the application can be used in decision support in other situations.

The advantages and disadvantages of the three multi-criteria decision optimization methods and techniques are presented in Table 1.

Table 1. Advantages and disadvantages of multi-criteria decision optimization methods and techniques

Method	Advantages	Disadvantages
SAW	- easy to understand and implement; - can be used for a wide range of decision problems; - can be used for cases with subjective criteria; - weights the criteria according to their importance; - provides a clear order of alternatives so that it is easy to understand and use; - suitable for situations where the criteria are independent of each other.	- the need to set weights for each criterion; - does not take into account interdependencies between criteria; - can lead to subjectivity in weighting; - may be affected by changes in weights; - cannot be used for problems with a large number of criteria.
Electre	- can be used in cases with subjective criteria; - can take into account interdependencies between criteria;	- requires establishing preference relations between alternatives; - can be complex in the case of a large number of

Method	Advantages	Disadvantages
	- allows the use of an acceptability threshold for alternatives.	alternatives and criteria; - can be subjective in establishing preference relationships
Onicescu	- can be used for a large number of alternatives and criteria; - can take into account interdependencies between criteria by using the correlation coefficient.	- subjective criteria are not taken into account; - can be influenced by extreme values in the decision matrix; - the need to establish weights and thresholds of acceptability

Source: author processing

Thus, choosing the right method must be in accordance with the specific needs and requirements of the decision-making problem, as well as the resources and skills of the decision-making team. It may also be useful to consider several methods and compare the results in order to reach a more informed decision.
While these methods and techniques can help optimize decisions, it is important to consider other factors, such as risk, uncertainty, and unintended consequences.

Overall, the use of these decision optimization methods and techniques can help to make more informed and better-informed decisions, which can lead to better and more effective outcomes in different application areas.

4. Conclusions

In conclusion, the use of multi-criteria decision optimization methods and techniques can be used in a variety of fields, including business, engineering, urban planning, healthcare, and others. Each method has specific advantages and disadvantages, and choosing the right method depends on several factors, such as:

- the purpose and nature of the decision problem - each method has advantages and disadvantages, so one method may be more appropriate than the others, depending on the context of the problem;
- data availability and quality - the SAW method requires accurate and reliable data, and the ELECTRE method involves a greater degree of subjectivity, while the Onicescu method is more flexible in terms of the type of data it can process;
- experience and skills of the decision team - the SAW method may be easier to understand and apply for people with no experience in multi-criteria analysis, whereas the ELECTRE method requires more expertise in mathematical and data analysis;
- time and budget conditions - the SAW method is often the quickest and cheapest way to reach a decision, but can be less accurate than the other two methods. While the ELECTRE method and the Onicescu method may be more laborious and costly, they can provide more accurate and robust solutions.

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