# Multi-criteria decision support methods for the selection of the optimum contractor: A case study of a passenger transfer centre

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**Abstract**: *Purpose*: The main purpose of the paper is to apply the TOPSIS method for selecting the optimal contractor for a passenger transfer center.

*Methodology*: The methodology is based on the use of TOPSIS, which determines the distance of decision alternatives from the ideal and anti-ideal solutions using evaluation criteria.

*Results*: Two different contractor rankings were obtained depending on the weights of the criteria. With equal weights, the best contractor is number 5, while with weights determined by formula (8), the best is number 4.

*Theoretical Contribution*: The paper contributes to the field of investment project management by demonstrating how the TOPSIS method can aid in decision-making for optimal contractor selection, thereby reducing the risk of erroneous decisions.

*Practical Implications*: The practical implications of this research are significant for investment projects, as the demonstrated methodology can be directly applied to the contractor selection process, potentially leading to more successful project outcomes.

**Keywords:** TOPSIS, logistics projects, passenger transfer centre

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## 1. Introduction

In recent decades, human mobility and average distances travelled have increased due to technological and social change (Groenendijk et al., 2018). In many countries, the car has become the preferred means for people to travel independently due to its convenience, speed and independence (Anable, 2005), resulting in traffic congestion and increased pollution (Beirão & Sarsfield Cabral, 2007). Although, as Groenendijk et al. (2018) point out, it is preferable to change travellers' habits and increase their interest in public transport, but its users have a negative perception of transfers and waiting times (Peek & Van Hagen, 2002). Daily journeys for many public transport users require transfers to complete, so a significant challenge in urban mobility is to improve transfers and guarantee a positive experience for travellers (Hernandez et al., 2016; Rossolov et al., 2021). A transport hub fulfils the function of connecting different modes of public transport and is characterised by many functional connections (Groenendijk et al., 2018).

It should be noted that there has recently been a shift towards a sustainable urban development paradigm, with public transport becoming the main mode of transport for residents (Rossolov et al., 2021). City authorities wishing to implement a passenger transport hub face several challenges, such as estimating costs, taking the time to implement the investment, and, importantly, selecting the right contractor (especially when decisions are complex and require the analysis of many criteria).

Multiple-criteria decision analysis (MCDA) or multiple-criteria decision making (MCDM) is a sub-discipline of operations research that provides a tool to support the subjective evaluation of a set of alternative decisions within a limited number of criteria (Lootsma, 1999; Nguyen et al., 2020). Due to the complexity of MCDA/MCDM, the following few factors can be identified as influencing this fact (Cinelli et al., 2022; Keeney, 1996; Keeney & Gregory, 2005; Ley-Borrás, 2015; Wątróbski et al., 2019):

– identification of the decision situation to be investigated,
– characterisation and generation of alternatives for implementation,
– development and identification of evaluation criteria,
– selection of MCDA/MCDM methods.

It should be emphasised that the number of methods used within MCDA has increased significantly over the last few decades (Alinezhad & Khalili, 2019; Cinelli et al., 2022; Greco et al., 2001; Hwang & Yoon, 1981).

In presenting the use of multi-criteria analysis methods, a hypothetical project was used: an interchange centre located in a city of more than 100,000 inhabitants in Poland. The aim of this study is, therefore, to attempt to apply the TOPSIS method to the selection of a contractor for a passenger transfer centre.

The article aims to test the applicability of multi-criteria methods in deciding on the selection of a project contractor. Among the many MDCM methods, the authors have taken the TOPSIS method as a stratagem, which allows for finding a solution closest to the ideal one.

## 2. Literature review

The main premise of multi-criteria methods is to enable the comparison of multiple projects described by multiple characteristics. The features used to describe the projects constitute the evaluation criteria, and a ranking of the projects can be created based on each feature individually. By analysing each attribute individually, a project can achieve a different ranking each time. The solution to this problem is multi-criteria methods, which are widely described in the literature and relate to various issues. A distinction is made between methods based on pair-wise comparison of decision options, based on a superiority relationship, using utility functions or benchmarks.

In literature, the most frequently raised problems are those regarding location selection(Bouayad-Agha et al., 2013; Chu, 2012; Ertuğrul & Karakaşoğlu, 2008; Farahani & Asgari, 2007; Martín et al., 2003; Tabari et al., 2012) choice of supplier (Chan & Kumar, 2007; Önüt et al., 2009) choice of strategy (Wey & Wu, 2007) or performance assessment (utility) (Bojkovic et al., 2010; Chamodrakas et al., 2009; Govindan et al., 2013). The most commonly used methods to solve these problems are primarily: Analytic Hierarchy Process (AHP)(Ertuğrul & Karakaşoğlu, 2008; Poh & Ang, 1999), fuzzy AHP (fAHP) (Chan & Kumar, 2007; Tabari et al., 2012), Analytic Network Process (ANP) (Tuzkaya et al.,

2008; Wey & Wu, 2007), fuzzy ANP (fANP) (Önüt et al., 2009), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Farahani & Asgari, 2007), fuzzy TOPSIS (fTOPSIS) (Ertuğrul & Karakaşoğlu, 2008; Govindan et al., 2013; Önüt et al., 2009), ELimination and Choice Expressing Reality (ELECTRE) (Bojkovic et al., 2010) and fuzzy Preference Ranking Organization Method for Enrichment Evaluations (fPROMETHEE) (Martín et al., 2003). A detailed breakdown of multi-criteria methods is provided in Table 1.

**Table 1: Taxonomy of MCDA methods**

| Method name | Available binary relations | | | | | Linear compensation effect | | | Type of aggregation | | | | Type of preferential information | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | P | Q | R | S | No | Totale | Partial | Single criterion | Outranking | Mixed | Deterministic | Cardinal | Non-deterministic | Ordinal | Fuzzy |
| AHP | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 |
| Electre I | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 |
| Electre II | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| Electre III | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| Electre IV | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| Electre TRI | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| Fuzzy PROMETHEE I | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| Fuzzy PROMETHEE II | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| Fuzzy TOPSIS | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 |
| PROMETHEE I | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| PROMETHEE II | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |
| TOPSIS | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |

*Source*: (Wątróbski i in., 2019).

The study's considerations included the TOPSIS method, which is characterised below. This method was used to select the best contractor for the passenger transfer hub.

## 3. Research method

The TOPSIS method (Technique for Order of Preference by Similarity to the Ideal Solution) aims to find the distance of the objects under consideration from the ideal and anti-ideal solution. This algorithm was presented in 1981 by Hwang and Yoon (Hwang & Yoon, 1981), although, according to Roszkowska & Wachowicz (2013), a similar approach was advocated much earlier by statistician Z. Hellwig.

In the classical version of the TOPSIS method, the decision problem is discrete. This means that at least some of the decision variables take discrete values, i.e. from a set equidistant from natural numbers (e.g. natural, integer or rational numbers). The calculation is done in several steps.

Stage one involves normalising the features according to one of the following formulae (Araujo et al., 2018; Brol, 2006; Çelen, 2014; Chakraborty & Yeh, 2009; Luczak & Just, 2020; Strahl, 1990):

$$z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \qquad \text{for i=1,2,…,m and j=1,2,…,n} \qquad (1)$$

$$z_{ij} = \frac{x_{ij}}{maxx_{ij}}, \qquad \text{for i=1,2,…,m and j=1,2,…,n} \qquad (2)$$

$$z_{ij} = \frac{x_{ij} - maxx_{ij}}{maxx_{ij} - minx_{ij}}, \qquad \text{for i=1,2,…,m and j=1,2,…,n} \qquad (3)$$

$$z_{ij} = \frac{1/x_{ij}}{\sqrt{\sum_{i=1}^{m} (1/x_{ij})^2}}, \qquad \text{for i=1,2,…,m and j=1,2,…,n} \qquad (4)$$

$$z_{ij} = 1 - \frac{x_{ij}}{maxx_{ij}}, \qquad\qquad \text{for i=1,2,...,m and j=1,2,...,n} \qquad (5)$$

$$z_{ij} = \frac{maxx_{ij} - x_{ij}}{maxx_{ij} - minx_{ij}}, \qquad\qquad \text{for i=1,2,...,m and j=1,2,...,n} \qquad (6)$$

Where: xij is the value of the i – this decision variant with respect to the j – th criterion,

Most commonly, formula (1) proposed by Hwang and Yoon (1981) is used for normalisation. Our article will use formula (1) to compare the final results. It should be added that the first three formulas (1) - (3) are used to normalise traits that are stimulants, while formulas (4)-(6) are used for features that are destimulants.

The next step is to take into account the weights attributed to the individual characteristics, according to a formula:

$$t_{ij} = w_j \cdot z_{ij}, \qquad\qquad \text{for i=1,2,...,m and j=1,2,...,n} \qquad (7)$$

Where wj is the weight of the j-th criterion and $\sum_{j=1}^{n} w_j = 1$.

The weights at this stage can be set the same for all criteria, but a formula can also be used:

$$w_j = \frac{|V_j|}{\sum_{j=1}^{n} |V_j|}, \qquad\qquad \text{for i=1,2,...,m and j=1,2,...,n} \qquad (8)$$

Where Vj is the coefficient of variation for the j-th feature.

Stage three is to determine the vector of values of the ideal solution a+ and the anti-ideal solution a-:

$$a^+ = (a_1^+, a_2^+, \ldots, a_n^+) := \left\{ \left( \max_{i=1,\ldots,m} t_{ij} \middle| j \in J_Q \right), \left( \min_{i=1,\ldots,m} t_{ij} \middle| j \in J_C \right) \right\} \text{for i=1,2,...,m and j=1,2,...,n} \qquad (9)$$

$$a^- = (a_1^-, a_2^-, \ldots, a_n^-) := \left\{ \left( \min_{i=1,\ldots,m} t_{ij} \middle| j \in J_Q \right), \left( \max_{i=1,\ldots,m} t_{ij} \middle| j \in J_C \right) \right\} \text{for i=1,2,...,m and j=1,2,...,n} \qquad (10)$$

Where JQ is the set of stimulants, and JC is the set of destimulants.

Once the ideal and anti-ideal solutions have been determined, the next step is to calculate the distances of the projects under investigation from these solutions. The most commonly used distance is the Euclidean distance:

$$d_i^+ = \sqrt{\sum_{j=1}^{n} \left( t_{ij} - a_j^+ \right)^2} \qquad\qquad \text{for i=1,2,...,m and j=1,2,...,n} \qquad (11)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} \left( t_{ij} - a_j^- \right)^2} \qquad\qquad \text{for i=1,2,...,m and j=1,2,...,n} \qquad (12)$$

The final step in the TOPSIS procedure is the determination of a ranking coefficient that determines the similarity of the objects to the ideal solution:

$$R_i = \frac{d_i^-}{d_i^- + d_i^+} \qquad\qquad \text{for i=1,2,...,m} \qquad (13)$$

The highest value of the Ri coefficient indicates the best solution (object) in the context of the considered linear ordering problem

## 4. Results and discussion

In order to achieve the aims of this paper and to test the TOPSIS method, it was necessary to identify the type of investment and the potential dilapidations involved in selecting an appropriate contractor for the project. The IntegraHub project is about the hypothetical selection of the optimum contractor for a modern passenger transfer centre (rail-bus) located in a city of more than 100,000 inhabitants in Poland. The Municipality of Poznań implements the project, which announces a tender for selecting the optimal contractor. Four criteria will be taken into account in choosing the best contractor for the IntegraHub investment project:
- Price;
- Realization time;
- Reputation = recommendations = previous projects realised;
- Complaints = number of complaints to previous realisations.

Table 2 shows the criterion values for the decision options; project implementers were rated on a scale of 1 to 15 due to each criterion. A value of 1 was considered the worst and 15 the best; due to each criterion being separate, a different project implementer can be selected. For example, about price, implementers numbered 5 and 6 are the most attractive, while with regard to the second criterion - delivery time - implementer number 1 should be selected. At the same time, it should be noted that the same implementer number 1 about price (criterion 1) and the number of complaints (criterion 4) rank last in the ranking regarding these criteria.

**Table 2: Criteria values for decision-making options**

| Project contractor (R) | CRITERIA | | | |
|:---:|:---:|:---:|:---:|:---:|
| | C1 | C2 | C3 | C4 |
| R1 | 1 | 13 | 12 | 2 |
| R2 | 12 | 5 | 6 | 1 |
| R3 | 10 | 5 | 14 | 11 |
| R4 | 1 | 9 | 10 | 4 |
| R5 | 14 | 12 | 12 | 8 |
| R6 | 14 | 12 | 6 | 10 |
| R7 | 13 | 8 | 15 | 9 |
| R8 | 7 | 9 | 9 | 15 |
| R9 | 3 | 2 | 1 | 11 |

*Source*: own calculations.

In the order after normalisation according to formula (1) for the considered criteria, two sets of weights were adopted:

Set 1: wi=0,25, for i=1,...4;

Set 2[1]: w1=0,30; w2=0,21; w3=0,22; w4=0,27.

When determining the weights, equation (8) was taken into account, in addition to the equal weights, to check whether changing the weights affects the ranking of the project implementers. Performing further calculations according to formulas (11) - (13), two different sets of distances from ideal $d_j^+$ and anti-ideal solutions were obtained $d_j^-$ (Table 3) and two different rankings for the project implementers (Table 4).

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1 The weights were established utilizing Formula 8.

**Table 3: Euclidean distances from ideal and anti-ideal solutions**

| Project contractors (R) | Weights | | | |
| | Set 1 | | Set 2 | |
| | $d_j^+$ | $d_j^-$ | $d_j^+$ | $d_j^-$ |
|---|---|---|---|---|
| R1 | 0,151 | 0,142 | 0,197 | 0,116 |
| R2 | 0,151 | 0,108 | 0,200 | 0,121 |
| R3 | 0,083 | 0,164 | 0,127 | 0,165 |
| R4 | 0,147 | 0,107 | 0,200 | 0,089 |
| R5 | 0,051 | 0,186 | 0,102 | 0,187 |
| R6 | 0,076 | 0,177 | 0,123 | 0,183 |
| R7 | 0,058 | 0,181 | 0,107 | 0,183 |
| R8 | 0,086 | 0,171 | 0,132 | 0,172 |
| R9 | 0,177 | 0,095 | 0,222 | 0,102 |

*Source*: own calculations.

**Table 4: Rank coefficient and ranking position**

| Project contractor (R) | Weights | | | |
| | Set 1 | | Set 2 | |
| | Ranking coefficient Rj | Ranking position | Ranking coefficient Rj | Ranking position |
|---|---|---|---|---|
| R1 | 0,485 | 6 | 0,370 | 3 |
| R2 | 0,419 | 8 | 0,377 | 4 |
| R3 | 0,665 | 5 | 0,564 | 5 |
| R4 | 0,421 | 7 | 0,308 | 1 |
| R5 | 0,785 | 1 | 0,646 | 9 |
| R6 | 0,699 | 3 | 0,599 | 4 |
| R7 | 0,756 | 2 | 0,631 | 8 |
| R8 | 0,665 | 4 | 0,566 | 6 |
| R9 | 0,349 | 9 | 0,315 | 2 |

*Source*: own calculation.

The calculations produced two completely different rankings of project contractors. Assuming equal weights for all criteria, the best implementer of the project should be considered the one with the number 5, then sequentially 7 and 6, while the worst implementers are the ones with the numbers 2 and 9. On the other hand, using the weights determined from formula (8), which can be considered more objective, based on the variability of the criteria, the best implementer is the number 4 and in order 9 and 1. At the same time, the least desirable contactors are numbers 7 and 9.

The criteria and implementers presented for consideration were identified at the beginning of the selection decision stage. The first point, not so much a point of contention but allowing for different results, is the possibility of using different formulas to normalise the critters. In order to determine how the weights are established, the authors believe that the use of formula (8) is the most objective in the absence of expertise. As well as the use of a formula other than the Euclidean distance for determining the distance from the ideal and antiderivative solution will affect the final results.

## 5. Discussion of results

The criteria presented for consideration and the project's implementers were clearly defined at the beginning of the decision-making phase. The first point, which is not so much a point of contention as it is a point that allows for different results, is the possibility of using other formulae to normalise the critters. In order to determine how the weights are established, the authors believe that the use of formula (8) is the most objective in the absence of expertise. As well as the use of a formula other than the Euclidean distance for determining the distance from the ideal and antiderivative solution will affect the final results.

Our findings have several important implications for practice, especially for business decision-makers concerning project (or contractor) selection, resource allocation or development strategies.

Firstly, the TOPSIS method can support decision-making in selecting the optimum contractor for investment projects carried out by both local and regional authorities and projects carried out by private companies. Secondly, the method is believed to reduce the risk of making a wrong decision when selecting a contractor, especially when decisions are made based on several criteria. This method allows each criterion to be weighted, which in turn allows potential project contractors to be assessed based on their ability to meet the expectations of the contracting authority (e.g. local government, private companies). Thirdly, in the broadest sense, this method allows for a better level of objectivity in the decision-making process for selecting the optimal project contractor.

## 6. Conclusion and policy implications

Selecting the best contractor for a logistics project is a knowledge-intensive endeavour and requires the right approach. The ability to determine the necessary project tasks, estimate the time and cost of project implementation, select project contractors, etc., are the basic problems to be solved during the planning phase. The implementation of logistics projects brings different types of opportunities and risks. It is natural to want to minimise risks by selecting the right contractor. Based on subjective criteria, good practice and expert experience, it is possible to make the best decision from an optimisation point of view.

To this end, the use of multi-criteria methods seems justified. Different methods are used for each of the logistics problems under consideration: others for optimisation problems, others for the classification problem and others for the ranking problem. Within each of these groups, a range of methods can be applied. Of course, an individual selection of solution methods must be made for each case.

The idea behind the method presented in this paper is that it is possible to find an ideal solution based on several criteria and appropriate transformations. The TOPSIS method allowed the making of an optimal contractor selection in the case under consideration. The authors are aware that the criteria used to evaluate the contractors are rather subjective, but as far as knowledge allows, they considered them to be the best from the point of view of project implementation.

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## Conflicts of interest

The authors declare no conflict of interest.

## Data availability

Some or all data and models that support the findings of this study are available from the corresponding author upon reasonable request.

## Citation information

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