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Application of AHP and ELECTRE III/IV methods to multiple level, multiple criteria evaluation of urban transportation projects

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Abstract

In this paper the authors carry out a multiple level, multiple criteria evaluation of 18 urban transportation projects. At each level of the hierarchical decision problem different multiple criteria ranking sub-problems have been structured and solved with the application of AHP method, ELECTRE III/IV method and their combination (AHP/ELECTRE III/IV). Thus, the computational phase allowed for testing the above mentioned multiple criteria ranking methods, i. e.: AHP and ELECTRE III/IV and analyzing their suitability for performing a multiple level, multiple criteria evaluation of transportation projects. Due to axiomatic differences between methods alternative aggregation formulas of the generated rankings by ELECTRE III/IV and AHP methods have been proposed. A multi - aspect discussion and comparison of generated results and applied methods have been presented.

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Keywords: Multiple Criteria Decision Making/Aiding; AHP and Electre III/IV methods; multiple level, multiple criteria evaluation of transportation projects;

1. Introduction

One of the major tasks in urban transportation management is monitoring the current condition of urban transportation and implementing specific projects to improve it. Assessment and selection of the proposed improvements and their variants necessitate analysis with the use of selected methodologies which provide appropriate tools (methods) (Beder, 2000; Belton & Stewart, 2002). Evaluation and selection of transportation projects (TP-s) (especially infrastructural ones) constitutes an important decision-making topic and is widely discussed in professional literature (Caliskan, 2006; Cascajo, 2005; Cascetta, 2009; Kruszynski, 2014; Zak, 2005). In the case of urban transportation, this problem is often interconnected with budget planning for a huge

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agglomeration and prioritizing the implementation of specific transportation-related investments.

From among project evaluation methodologies presented in the literature (see section 2.3) (Gercek, Karpak, & Kilincaslon, 1998) multiple-criteria decision making/aiding (MCDM/A) enjoys increasing popularity. MCDM/A methods allow for taking into account subjective decision maker's (DM's) and interveners' preferences and transforming them into objective quantitative measures (Zak, 2005). This objectification and transparent way of caring out the evaluation accounting for multiple aspects are especially valuable for analyzing transportation projects (Kruszynski, 2014). Therefore, in many reports authors present practical applications of MCDM/A methodology for analysis, evaluation and ranking of specific transportation-related investments (Gercek, Karpak, & Kilincaslon, 1998; Caliskan, 2006; Cascajo, 2005; Hayashi & Morisugi, 2000; Morisugi, 2000).

In this article the authors define the question of evaluating urban transportation projects (TP-s) as a multiple level, multiple criteria ranking problem. This problem is associated with assessment of transportation investments of different character, including projects concerning public transportation, private transportation, individual non-motorized transportation (pedestrians, cyclists) and integration of transportation modes. Assessment of the above mentioned projects is carried out on three levels of city governance: strategic, tactical and operational. On each level of the analysis the TP-s are evaluated from different perspectives, including: subject-matter perspective (at the operational level), transportation policy perspective (at the tactical level) and the overall metropolitan area perspective (at the strategic level). As a result, different families of criteria are applied to evaluate the projects at those levels and three different rankings of the projects are generated. These rankings require overall aggregation to produce the final order of TP-s. In addition, at the operational - subject-oriented level different categories of urban transportation projects (e.g. public transportation, non-motorized transportation projects) are evaluated separately by the respective and appropriately customized families of criteria. Consequently, a certain number of rankings, corresponding to the number of the projects' categories must be produced at the operational level. As a result, several aggregation procedures are required to generate a final ranking of all considered transportation projects (Kruszynski & Zak, 2015).

It is worth emphasizing that at each level of the analysis respective multiple criteria ranking problems are considered. They can be solved with the application of various multiple criteria ranking methods. In this paper the authors test two MCDM/A methods, i.e.: AHP and ELECTRE III/IV. They carry out the computational experiments resulting in the evaluation of 18 urban TP-s. The analysis is performed within a universal methodological framework of multiple criteria evaluation of TP-s. At each level of the hierarchical decision problem, different multiple criteria ranking sub-problems have been structured and solved with the application of AHP method, ELECTRE III/IV method and their combination (AHP/ELECTRE III/IV). Due to axiomatic differences between methods, alternative aggregation formulas of the rankings generated by ELECTRE III/IV and AHP methods have been proposed. A multi - aspect discussion and comparison of generated results and applied methods have been presented.

The article is composed of 5 sections. Sections 1 presents preliminary considerations and introduces the reader into the topic considered. Section 2 presents methodological background of the research. It contains the theoretical introduction into the field of Multiple Criteria Decision Making/Aiding (MCDM/A) and the description of MCDM/A methods: AHP and ELECTRE III/IV, applied in the phase of computational experiments. Section 3 characterizes multiple level, multiple criteria evaluation of transportation projects. Section 4 is focused on the construction of variants/TP-s, definition of the consistent families of criteria and presentation and analysis of results of computational experiments. Section 5 presents conclusions and summary of the article. The paper is supplemented by the list of references.

2. Theoretical background of the research

2.1 The Methodology of MCDM/A

Multiple Criteria Decision Making/Aiding (MCDM/A) is a field of study that originates in Operations Research - OR (Hillier & Lieberman, 2001) and focuses its efforts on solving multiple criteria decision problems. These problems are such complex decision situations in which several, often contradictory, points of view must be taken into account (Vincke, 1992). The multiple criteria decision problem may refer to three alternative situations that consist in (Roy, 1990; Vincke, 1992):