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Multiple criteria evaluation of different redesign variants of the public tram system

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Abstract

The paper presents a multiple criteria evaluation of ten redesign variants of the public tram system in one of the medium sized cities in Poland. The variants have been constructed heuristically, based on "common sense", best practices and authors' expert knowledge in the field. Multiple criteria evaluation of the proposed variants has been performed with the application of a consistent family of criteria that includes social, economic, technical and environmental aspects. It also represents the interests of the Decision Maker and different stakeholders. The authors have defined different models of preferences. The decision problem, formulated as a multiple criteria ranking problem has been solved with the application of selected Multiple Criteria Decision Making/ Aiding MCDM/A methods, such as: AHP and ELECTRE III/IV. The authors have carried out a series of computational experiments and have compared their results with intuitive decision making process carried out in the local Town Hall. The proposed methodology can be viewed as a decision support tool for governmental officers and local administration.

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Keywords: Multiple Criteria Evaluation; Public Tram System; Redesign; AHP method; Electre III/IV method;

1. Introduction

The growing wealth of societies and consequently a greater access to passenger cars is responsible for the significant increase of the motorization index with a simultaneous fall in public transportation usage (Leea,

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Rivasplata, 2001). This observation indicates that concrete actions should be undertaken to change this trend and encourage people to use public transportation more frequently and with more trust and desire. Unfortunately, many public transportation systems, including Polish ones, are maladjusted to the needs of the customers and not properly managed (Witkowski, Kiba-Janiak, 2012; Żak, Fierek, 2007). Therefore, they require comprehensive redesign resulting in the improvement and enhancement of the service delivered. Redesign of the public transportation system is a complex process that consists in introducing substantial changes in several of its critical components. The redesign of the public transportation system may involve: route changes, relocation of stops, construction of integrated multi-modal transfer terminals, fleet reassignment, better coordination of schedules, and many others. As a result different variants – transportation solutions for the public transportation system can be constructed. The proposed variants should be evaluated and the best/most desired option should be selected. There are several approaches and methodologies which carry out such an evaluation, including: cost-benefit analysis (CBA) (Nickel et al, 2009), cost-effectiveness analysis (CEA), regional economic impact study (REIS), environmental impact assessment (EIA) (De Brucker et al, 2011) and Multiple Criteria Analysis (MCA) (Levine, Underwood, 1996; Żak et al, 2014).

It is very common that during the redesign process the analysts face the challenge to consider the interests of different stakeholders and find solutions that would balance these interests accordingly. In public transportation the major groups of stakeholders include (Żak, Fierek, 2007): local authorities, operators of public transportation system, passengers and local community. In many cases the expectations of these groups are in contrast and a comprise must be found to satisfy them to a certain extend. For these reasons MCA, often called MCDM/A, gains increasing popularity among the above mentioned methodologies as a tool of evaluation of transportation projects, solutions and system (Lee, 2000, Novak et al, 2012; Żak, Thiel, 2001).

In this paper the authors have presented the methodology of designing and evaluating alternative variants of the tram transportation system. They have focused their analysis on a comprehensive, multiple criteria evaluation of the generated variants and have shown how the evaluation of the tram public transportation system should be performed. The authors have developed a universal, consistent family of criteria that can be applied to evaluate different redesign variants of the public tram transportation system including different expectations of the Decision Maker (DM) - local authority and various stakeholders such as: passengers, operator and local community. They have also presented how to model the DM's and stakeholders' preferences and how to generate rankings of the designed variants. In the computational phase they have proven the applicability of two MCDM/A methods: AHP and ELECTRE III/IV to the evaluation of the public tram transportation systems.

The authors have made an attempt to answer the following research questions: Which of the two applied methods - AHP or Electre III/IV - is more useful for the evaluation of the redesign variants of the public tram system? What are the major similarities and differences between AHP and Electre III/IV methods in terms of: defining and scaling criteria, modeling preferences, generating final results? How the generated rankings compare to the intuitive decisions made by local authorities (government)?

The paper is organized as follows. The first section provides general background for the performed analysis. The second section introduces the readers into MCDM/A methodology, with particular emphasis on description of AHP and Electre III/IV methods. The following section presents the considered decision problem statement. Section four shows computational experiments and their results, which are compared results to the intuitive decision made by the local authorities. In the last section the authors formulate conclusions and the further directions of the research.

2. Multiple Criteria Decision Making/Aiding in Public Transportation

MCDM/A (Steuer, 1977; Vincke, 1992; Żak, 2005; Ehrgott, 2005; Belton, Steward, 2003) is a field of study that concentrates on solving the so called multiple criteria decision problem, i.e. a situation in which, having defined a set of actions/variants/solutions $\boldsymbol{V}$ and a consistent family of criteria $\boldsymbol{F}$ the DM tends to (Vincke, 1992):

- determine the best subset of actions/variants/solutions in $\boldsymbol{V}$ according to $\boldsymbol{F}$ (choice problem),
- divide $\boldsymbol{V}$ into subsets representing specific classes of actions/variants/solutions, according to concrete classification rules (sorting problem),
- rank actions/variants/solutions in $\boldsymbol{V}$ from the best to the worst, according to $\boldsymbol{F}$ (ranking problem).

The MCDM/A methodology distinguishes major stakeholders of a decision process: a DM, an analyst and