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The influence of the scenario and assessment method on the choice of road alignment variants

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ABSTRACT

An efficient road network plays a key role in the economic development of almost any country. Road construction, apart from its many benefits, has also a negative impact on the natural environment causing its deterioration or division, introduces changes in area management, or may be the cause of social conflict. The decision to choose the most beneficial road alignment variant should take into account all of these aspects. It is therefore a multicriteria issue, based on transport, economic, social and environmental criteria. This article presents the influence of the assessment method of variants, criteria and their weights, as well as preference scenarios of road alignment with the example of the section of the S61 expressway, which is a part of the first Trans-European Transport Network (TEN-T). Four road alignment variants were analysed using the AHP, SAW and TOPSIS methods, with different sets of criteria weights and various preference scenarios. It has been shown, that the used variant assessment method, the criteria and their weights all have a significant influence on the results of the analysis and there is need for more uniform rules in reference to the methodology of conducting multicriteria analyses in designing road alignment.

1. Introduction

The problem of the construction of roads in each country is an important issue, since an efficient road network plays a crucial role in the economic development. The decision to choose the most beneficial road alignment variant should take into account the economic and transport criteria, as well as problems connected with the everyday lives of local communities and environment protection. This is why before commencing the designing work, an analysis of the road's influence on the environment is conducted, and its best alignment in relation to the most precious local resources is determined (Geneletti, 2005). The choice of the optimal variant is a difficult and complicated task, and the multicriteria analysis is the most common method of facilitating the decision making process in a situation where there are many alternative choices to take into account. It is based on an appropriate choice of assessment criteria and importance values of mostly transport, environmental, economic and social criteria (De Silva and Tatam, 1996; Kalamaras et al., 2000; De Luca et al., 2012). Researchers also point towards a wider division of criteria (Vickerman, 2000; Abbas, 2003; Cundric et al., 2008). In the multicriteria analysis both the quantity and quality criteria can be taken into account (Yelda and Shrestha, 2003; Jakimavicus and Burinskiene, 2009; Haghighat, 2011).

There are many known methods for conducting multicriteria analyses. With the choice of the road alignment the methods of the French school based on the principle of exceeding are taken into account as well as the American school often called the methods of the monocriteria synthesis, introducing the normalization of the criteria which enables their mutual comparison. The most often used methods of the French school are the ELECTRE and PROMETHEE family methods: ELECTRE (Elimination et Choice Translating Reality) i PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations). However, there exists a wide group of less popular methods which are based on the main idea taken from the ELECTRE methods. The methods mentioned are ORESTE, QUALIFLEX, REGIME, ARGUS, MELCHIOR.

The ELECTRE method was used to choose the waste management system (Hokkanen and Salminen, 1997), and the PROMETHEE method to assess the investment projects (Nowak, 2005).

The American school methods are AHP (Analytic Hierarchy Process), SAW (Simple Additive Weighting), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), COPRAS (Complex Proportional Assessment), VIKOR (Tudela et al. (2006) used

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the AHP method as an alternative to the Cost-Benefit Analysis method (CBA) to improve a part of the road system in the Chiguayante district in Chile. The results obtained from the AHP and CBA methods varied significantly. It has been concluded, that the society should take part in the decision making process, which would allow to obtain precise and up to date information about the projects. Moreover, a number of variants needs to be considered in order to compare their influence on the natural environment and society.

The SAW method was used to assess transport network development scenarios for the city of Vilnius (Jakimavicus and Burinskiene, 2009). A comparative analysis of the SAW and COPRAS methods can be found in Podvezko (2011). In the SAW method, the values of the criteria are maximized, and minimising criteria should be converted to maximising. In the COPRAS method, the maximizing and minimizing criteria are dealt with separately.

The TOPSIS method was used to rank roads according to safety level (Haghighat, 2011). The road safety coefficient was determined based on various quantity and quality criteria. A comparative analysis of the TOPSIS and VIKOR methods is presented in the work by (Opricovic and Tzeng, 2004) and it shows that the methods use different ways of normalization of the criteria and introduce different aggregating functions. This, however, does not influence the end values of the variants.

Sayers et al. (2003) have confirmed the possibility of using a linear model, by calculating the weighted sum, for assessing transport projects and suggest using a flexible approach to determining criteria weights – setting limits for relative criterion weight values instead of trying to determine an exact value. This leads to a clear and flexible decision making process. The preferences, which led to the final result, will be clearly determined and available to the public opinion which will reduce the risk of random or one-sided decisions.

(Gallo et al., 2011; Cipriani et al., 2012) have used a heuristic procedure and a genetic algorithm in order to find the optimal bus networks with the assumption of a flexible demand. (Gao et al., 2004) has presented a two-level model of designing networks for the transport system using the heuristic algorithm.

While selecting the road alignment, the criteria chosen to assess the variants are usually grouped together as environmental, social, economic and transport. Each criterion is assigned an appropriate weight, accordingly to its significance. These weights modify the criteria values accordingly to the preferences of the governing body and may be determined with them or by experts. In a situation when the governing body alone determines the weights of the criteria, it has significant influence on the results of the analysis, and the chosen road alignment is to a large extent based on that body's preference. Introducing experts to this process is a much better solution, along with studying the degree of the assessment agreement correlation by using statistical tests, such as the Kendall's concordance test (Legendre, 2005). The measurement of the co-dependency is Kendall's *W*. The *W* coefficient can have a value from '0' (no concordance) to '1' (complete concordance). A high *W* coefficient value is interpreted as the agreement of experts in assessing the variants. One of the possible algorithms for solving the problem is the usage of a balanced approach – all criteria groups have the same weight (Freudensprung et al., 1995; Janic and Reggiani, 2002; Geneletti, 2005).

In order to assess the variants in a multicriteria analysis, the sensitivity analysis is also used, which allows to assess how the variant ranking changes when the weights of individual criteria change (Freudensprung et al., 1995; Kalamaras et al., 2000; Janic and Reggiani, 2002; Geneletti, 2005). Freudensprung et al. (1995) when determining the Brenner transport corridor in the Alps, have analysed six preference scenarios: indifferent, ecological I, ecological II, ecological – cost mix, democratic, network efficiency. Kalamaras et al. (2000) have used the variant sensitivity analysis to choose the motorway alignment with the following preference scenarios: minimising construction problems, minimising influence on the environment, maximising economic results, and maximising functionality. The chosen weights in the individual preference scenarios allowed them to choose the most beneficial motorway alignment variant. Janic and Reggiani (2002) have conducted a multicriteria analysis of the possible locations for an airport with these three preference scenarios: the first intended to equate the weights for all the criteria, the second one used weights with even distribution taken from a simulation, the third scenario used weight values determined by an entropy method. Geneletti (2005) in order to assess the variants of land corridors used three preference scenarios: neutral, ecological and socio-economic.

The presented review of the chosen topics in the multicriteria analysis subject point to a series of crucial problems in the decision making process. The aim of this article is to assess the influence of the chosen variant assessment method, the chosen criteria and their weights, and the used preference scenario on the choice of road alignment. The analysis was conducted using the AHP, SAW and TOSIS methods with the example of a section of the S61 expressway, which is a part of the first Trans-European Transport Network (TEN-T) Helsinki–Tallin–Riga–Kaunas–Warsaw.

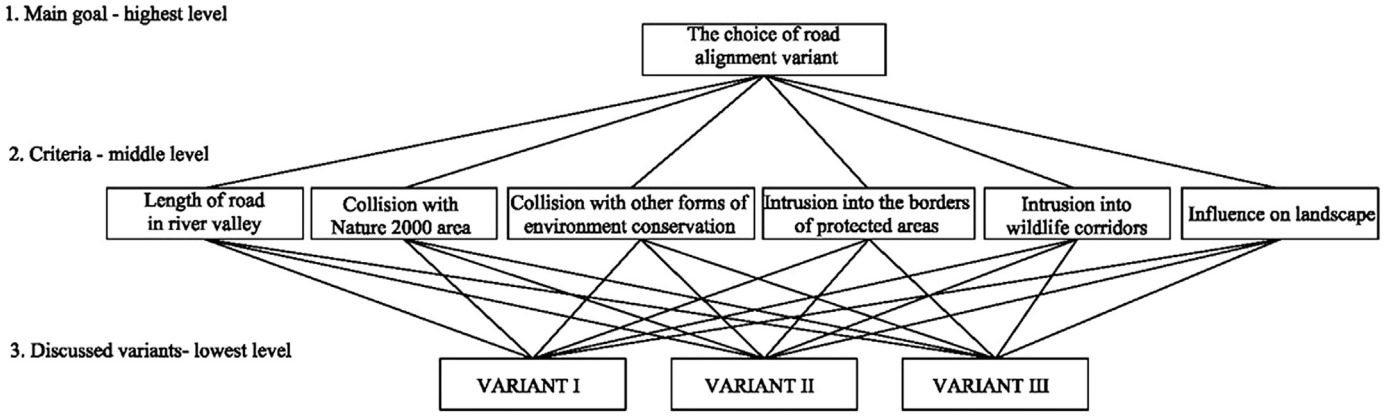

Fig. 1. Hierarchy structure for the choice of road alignment variant.