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Road and Rail Infrastructure III

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RAILWAY INVESTMENT PLANNING USING DYNAMIC PRIORITIES

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Abstract

Making a company investment plan is a complex and difficult management issue. Project selection and ranking are crucial steps for the company's success in the market. Strategic decisions, such as the development of a project investment plan, depend on many factors, with different relevance usually changeable over time. Some relationships of the system's elements are functions of time. The subject of this paper is time dependent decision making in transport project management. Several transport projects have been evaluated using Dynamic Priorities in Multi-criteria decision making. Here we consider rail investment projects as part of the Serbian railway network.

Keywords: project management, rail projects' evaluation, dynamic priorities

1 Introduction

Making a company investment plan is a complex and difficult management task [1, 2, 3, 4]. Transport projects evaluation has been very often a crucial step in the transport company's success in the market. The decision making in investment planning is a very complicated process because of many relevant factors, such as: stakeholders (owners, regulators, market, politicians…), system boundaries, transparency, and heterogeneous criteria [5].
The author of [4] in his PhD Thesis emphasized that the modeling process should be seen as a creative, dynamic and cyclic process. Decision makers are confronted with the difficult problem of evaluating and choosing among various alternatives of transport projects. Traditionally, Cost-Benefit analysis, CBA, is used as a support in the decision making process in transport projects planning. However, multi-criteria decision analysis has been promoted to be used in the transport sector to overcome some of the shortcomings of CBA [1, 2, 3, 4]. In this paper authors also suggest the usage of the multi-criteria decision making approaches for transport projects' evaluation.
Good decisions depend on the conditions in the future, and conditions vary over time, so making good decisions require evaluation of what is more likely, or what is more desirable during different time periods. This is the crucial reason for using the dynamic approach in the decision making process. Dynamic judgments and the dynamic approach to transport projects' evaluation is the topic of this paper. Basic assumptions of the applied mathematical computation are defined in the book [6]. There are situations in which changes occur in the structure of the problem, some new criteria can be added or old ones removed. Sometimes the judgments about the criteria change but the criteria remain the same. There are still others in which the judgments about the criteria remain the same, but the judgments about alternatives change over time. Finally, all these combinations are possible in practice [6]. The authors of [7] analyzed risks in megaprojects, after defining all relevant risks the special

focus was on the dynamic relations in the model. The Systems dynamics methodology was explained as a tool for better modeling and analyzing the behavior of complex systems. This approach has been used by researchers and project managers to understand various social, economic and environmental systems in a holistic view.
The authors of [8] suggested a new multicriteria analysis approach, with the following characteristics: unification of the criteria, differentiation of the project's performance over time, as a dynamic variable, and a new approach for the transformation of the physical scales to artificial ones. The application of the proposed approach is demonstrated on the example of the transportation infrastructure investments.
The aim of this paper is time dependent decision making in transport project management. Numerous transport projects have been evaluated using Dynamic Priorities in Multi-criteria decision making. This paper is organized as follows. After the Introduction, the second section, named applied methodology, contains basic assumptions of Analytical Hierarchy Process (AHP). The third section, the model for railway investment planning, presents the developed model with all system elements and their mutual relations. Results and discussion is the topic of the fourth section. Finally, the last section is dedicated to concluding remarks.

2 Applied methodology

Analytical Hierarchy Process (AHP, developed by Thomas Saaty) is one of the most popular approaches for Multi-criteria decision making. It is used in the analysis of decision-making and decision-making to solve complex problems whose elements are the objectives, criteria, sub-criteria and alternatives. AHP is one of the very popular approaches and because its ability to identify and analyze the inconsistency of the decision makers in the process of decompression and evaluation of the elements of the hierarchy. AHP in some way mitigates this problem by measuring the level of inconsistency and informs decision-makers about that. This is a static approach, which used fundamental Saaty scale to represent priorities. Expending the AHP approach it's possible to cope with the time – dependent priorities. This new approach is called Dynamic Hierarchy Process (DHP) [9]. Time-dependent decision-making, i.e. dynamic decision-making is something that is often necessary. But these alternatives may evolve over time, together with our preference for them, such as, for example, the actions of the stock market whose prices are constantly changing over time. Dynamic decision making is a reality, not a complicated concept that can be ignored. It is necessary for the technical design problems in which the effects of several project factors change over time and must make the compromise between them, to allow the system to react differently and continuously over his work time. A typical form of the matrix in a dynamic form:

$$A(t) = \begin{bmatrix} a_{11}(t) & a_{12}(t) & \cdots & a_{1n}(t) \\ a_{21}(t) & a_{22}(t) & \cdots & a_{2n}(t) \\ \vdots & \vdots & & \vdots \\ a_{n1}(t) & a_{n2}(t) & \cdots & a_{nn}(t) \end{bmatrix} \quad (1)$$

$a_{ij}>0, a_{ji}(t)=a_{ij}^{-1}(t)$ in discrete situation, when A(t) is consistent, we have $a_{ij}(t)=w_i(t)/w_j(t)$.
It is preferable that you first obtain weights for different time moments numerically solving the entire problem, and then these values approximate time-dependent curves. All relevant equations are developed in [9].

3 The model for railway investment planning

Developed model has the network structure, including four clusters (Figure 1). Each cluster has a certain number of elements, which is explained in this section in detailes. Considered sections (Rail Corridor X in Serbia) are presented in Table 1 [1, 2 , 3].

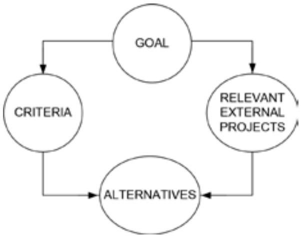

Figure 1 Considered model

Table 1 The considered alternatives with the lengths

Section	Alternative	Length of section [km]	Number of tracks
A_1	Šid-Stara Pazova	116	Double-track
A_2	Subotica-Stara Pazova	153	Single-track
A_3	Resnik-Mladenovac-Velika Plana	70	Single-track
A_4	Velika Plana-Stalać	86	Double-track
A_5	Stalać-Đunis	17	Single-track
A_6	Đunis-Trupale	40	Double-track
A_7	Niš-Preševo	173	Single-track
A_8	Niš-Dimitrovgrad	104	Single-track

All projects are already a part of the "Strategy for the development of railway, road, water, air and intermodal transport in the Republic of Serbia from 2008 to 2015". The purpose of the model in this paper is to rank rail investment projects, considering the financial and operating aspects: C_1 – Cost-benefit ratio, C_2 – Criteria of speed restriction, C_3 – Criteria of rail infrastructure capacity utilization, C_4 – Criteria of inconsistency with AGC & AGTC and C_5 – Criteria of traffic volume [2]. Based on the explanation [2], all defined criteria for considered sections are calculated. The values are given in Table 2. Using these data the pair-wise comparison matrices are developed. The main idea is that alternative with which it can be achieved higher effect is better ranked. The matrix of a criteria comparison is made by expert's recommendation.

Table 2 The calculated values of considered criteria for all alternatives

Alternative	C_1 [%]	C_2 [train hours/km]	C_3 [%]	C_4 [%]	C_5 [train/day]
A_1	0.47	93	17/17	0.014	25
A_2	0.45	24	75	0.084	48
A_3	0.29	333	61	0.192	52
A_4	0.07	31	23/23	0.048	40
A_5	0.08	14	45	0.100	44
A_6	0.05	14	23/23	0.010	44
A_7	1.66	9	34	0.285	23
A_8	2.84	12	36	0.267	16

The relevant external projects [1, 3] can be national or domestic, infrastructure, ecological or social projects, etc. These projects has high importance in the model of transport projects evaluation, having in mind that the transport network is very dependent of its surrounding (including the transport system in the considered country but also neighboring countries). Choosing the relevant external projects should be done by company management or by experts. Suggested relevant external projects in this model are: X – Vidin-Calafat Bridge, Y – Rehabilitation of Corridor IV and Z – Privatization of Port "Bar". Project X will take flows of goods and passengers from Corridor X and make better service quality on Corridor IV. With project Y the competitive Corridor IV becomes stronger comparing to Corridor X, and with the aim to keep the same freight volume transport on Corridor X, the service quality should be improved. Project Z would increase the volume of freight transport from Montenegro, through Serbia, to Hungary.
We suggested using the dynamic approach for defining the priorities of relevant external projects. Here is explanation for this proposal. One relevant external project has been already realized, Vidin-Calafat Bridge, project X (opened 14. June 2013). The end of the second project, the rehabilitation of Corridor IV is planned for 2020. Project Z, privatization of Port "Bar" will be realized very soon, but its effects are going to be visible in next few years. We assume that relevant time horizon for consideration is from 2014 to 2020 (at that moment all named external projects will be finished).

4 Results and discussion

The model has two parts, static and dynamic. Static part means comparing projects by criteria. This is done by using the Super Decisions software. The dynamic part presents projects evaluation by the relevant external projects. Mathematical computation for this part is done in Matlab. Table 3 presents the alternatives' weights relative to the criteria. Calculations are done in the software by using the well-known equations from the AHP approach.
The authors assumed that relative priorities of relevant external projects are time-dependent values. Here are pair-wise comparison matrices for relevant external projects, Table 4. Based on the data from Table 4, the functions for priorities are defined (Table 5).

Table 3 Alternatives' weights relative to criteria

C_i	C_1	C_2	C_3	C_4	C_5	**Weights**
A_i	0.256	0.445	0.182	0.041	0.076	
A_1	0.051	0.211	0.314	0.022	0.037	0.168
A_2	0.237	0.113	0.132	0.044	0.097	0.144
A_3	0.237	0.045	0.063	0.022	0.151	0.105
A_4	0.051	0.075	0.021	0.083	0.220	0.070
A_5	0.237	0.045	0.063	0.083	0.151	0.107
A_6	0.026	0.028	0.314	0.286	0.037	0.091
A_7	0.019	0.045	0.063	0.286	0.020	0.050
A_8	0.142	0.437	0.030	0.173	0.287	0.265
Sum	1	1	1	1	1	1

Table 4 Pair-wise matrices for relevant external projects

	2014			**2017**			**2020**		
	X	Y	Z	X	Y	Z	X	Y	Z
X	1	3	5	1	1	4	1	1	1
Y	0.333	1	4	1	1	3	1	1	1
Z	0.2	0.25	1	0.25	0.333	1	1	1	1

Table 5 Dynamic priorities for relevant external projects

	X	**Y**	**Z**
X	1	2.875–0.643t	5.333–0.067t
Y		1	4.167t–0.5t
Z			1

According the data from the table 5:

$$a_{12} = 2.857 - 0.643t \quad (R^2 = 0.964) \tag{2}$$

$$a_{13} = 5.333 - 0.067t \quad (R^2 = 0.92) \tag{3}$$

$$a_{23} = 4.167 - 0.5t \quad (R^2 = 0.964) \tag{4}$$

where:

R^2 the R squared values, indicates how well data points fit a statistical model;
t time horizon: 2014 (t=1), 2017 (t=2) and 2020 (t=3).

Thereafter, using the following equations [9], the weights for relevant external projects can be obtained. This calculation is made in Matlab.

$$\lambda_{max} = (a_{13} / a_{12}a_{23})^{1/3} + (a_{12}a_{23} / a_{13})^{1/3} + 1 \tag{5}$$

$$\Delta = a_{12}a_{23} + a_{13}(\lambda_{max} - 1) \tag{6}$$

$$D = a_{12}a_{23} + a_{13}(\lambda_{max} - 1) + (\lambda_{max} - 1)a_{23} + (a_{13} / a_{12}) - 1 + (1 - \lambda_{max})^2 \tag{7}$$

$$w_{e_X} = \frac{\Delta}{D} \tag{8}$$

$$w_{e_Y} = \frac{(\lambda_{max} - 1)a_{23} + (a_{13} / a_{12})}{D} \tag{9}$$

$$w_{e_Z} = \frac{-1 + (1 - \lambda_{max})^2}{D} \tag{10}$$

where:

$w_{ext}, w_{eyt}, w_{ezt}$ are weights of relevant external projects, for X,Y,Z, $t = \overline{1,3}$

The following graphs (Figure 2) are made by using the Matlab.

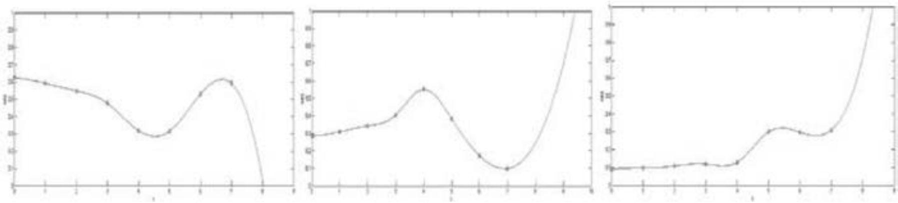

Figure 2 Weights w_{ext}, w_{eyt} and w_{ezt} for relevant external projects X, Y and Z

The weights of alternatives relative to criteria, w_{cj}, are constant value (Table 3), but the weights of alternatives relative to external projects, w_{emt}, are time dependent. We assume that the criterion has the weight 0.7, and the relevant external projects 0.3 for the whole model. Final weights of alternatives in the model should be calculated by following equation (Table 6):

$$w_{A_i t} = 0.7 w_{c_j} + 0.3 w_{e_m t} \quad , \text{ for } \; i = \overline{1,8}, \; t = \overline{1,3}, \; j = \overline{1,5} \tag{11}$$

Table 6 Alternatives' weights relative to external projects and final obtained results of the whole model through time horizons

	2014		2017		2020	
	w_{em1}	w_{ai1}	w_{em2}	w_{ai2}	w_{em3}	w_{ai3}
A_1	0.164	0.168	0.169	0.168	0.200	0.178
A_2	0.145	0.144	0.144	0.144	0.133	0.141
A_3	0.145	0.117	0.144	0.117	0.133	0.113
A_4	0.145	0.092	0.144	0.092	0.133	0.089
A_5	0.145	0.118	0.144	0.118	0.133	0.115
A_6	0.145	0.107	0.144	0.107	0.133	0.104
A_7	0.055	0.052	0.056	0.052	0.067	0.055
A_8	0.055	0.202	0.056	0.202	0.067	0.206

The final alternatives' rank is presented in the Figure 3. The main conclusion is that the relative importance of the alternatives is not changeable through the time, in this case study. However, during the time, some alternatives become more (A_1, A_7 and A_8) or less (A_2, A_3, A_4, A_5 and A_6) dominant.

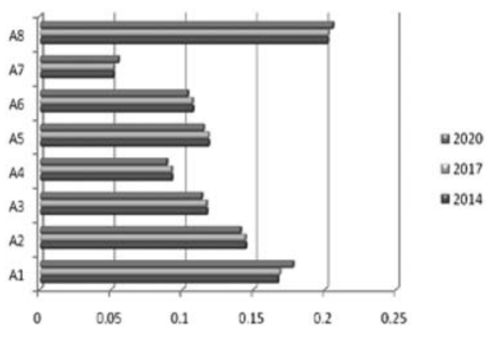

Figure 3 Final alternatives weights through time horizons

5 Conclusions

The model for decision making as a support system in decision making process should have flexible structure, to be easy to change the model according the changes in its surrounding. Decision makers sometimes need a model which take into account the changes of system's elements or changes in system's surrounding. This model presents the results with all possible modifications and gives the suggestions for all of them. The developed model takes into account changes in system's surrounding, with consideration of the relevant external projects, but also includes the changes of elements' priorities over time horizons, giving the final alternatives weights through time horizons. The analyzed case study was Rail Corridor 10 in Serbia. The main conclusion is that the relative importance of the alternatives in this model is not changeable through the time. However, during the time, some alternatives become more or less dominant. With respects to future studies, we recommend conducting the relevant stakeholders and their influences on the decision making process. Very often, there are dynamic stakeholders' preferences, changeable over time.

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