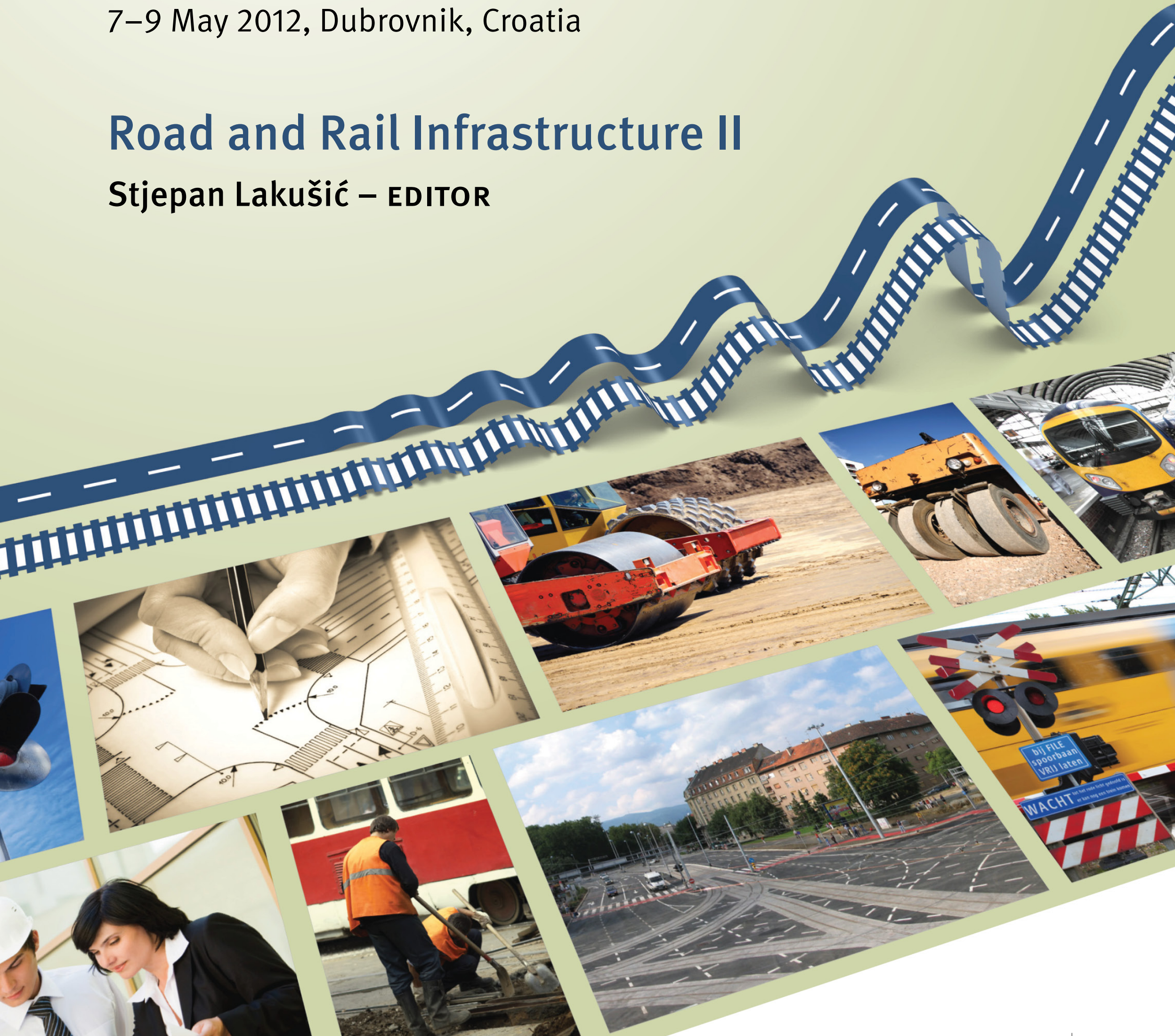
CETRA[2012]

2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

Stjepan Lakušić – EDITOR



Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA[2012]
2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

TITLE
Road and Rail Infrastructure II, Proceedings of the Conference CETRA 2012

EDITED BY
Stjepan Lakušić

ISBN
978-953-6272-50-1

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Katarina Zlatec · Matej Korlaet

COPIES
600

A CIP catalogue record for this e–book is available from the National and University Library in Zagreb under 805372

Proceedings of the
2nd International Conference on Road and Rail Infrastructures – CETRA 2012
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

ORGANISATION

CHAIRMEN

Prof. Željko Korlaet, University of Zagreb, Faculty of Civil Engineering
Prof. Stjepan Lakušić, University of Zagreb, Faculty of Civil Engineering

ORGANIZING COMMITTEE

Prof. Stjepan Lakušić
Prof. Željko Korlaet
Prof. Vesna Dragčević
Prof. Tatjana Rukavina
Maja Ahac
Ivo Haladin
Saša Ahac
Ivica Stančerić
Josipa Domitrović

All members of CETRA 2012 Conference Organizing Committee are professors and assistants of the Department of Transportation, Faculty of Civil Engineering at University of Zagreb.

INTERNATIONAL ACADEMIC SCIENTIFIC COMMITTEE

Prof. Ronald Blab, Vienna University of Technology, Austria
Prof. Vesna Dragčević, University of Zagreb, Croatia
Prof. Nenad Gucunski, Rutgers University, USA
Prof. Željko Korlaet, University of Zagreb, Croatia
Prof. Zoran Krakutovski, University Sts. Cyril and Methodius, Rep. of Macedonia
Prof. Stjepan Lakušić, University of Zagreb, Croatia
Prof. Dirk Lauwers, Ghent University, Belgium
Prof. Giovanni Longo, University of Trieste, Italy
Prof. Janusz Madejski, Silesian University of Technology, Poland
Prof. Jan Mandula, Technical University of Kosice, Slovakia
Prof. Nencho Nenov, University of Transport in Sofia, Bulgaria
Prof. Athanassios Nikolaides, Aristotle University of Thessaloniki, Greece
Prof. Otto Plašek, Brno University of Technology, Czech Republic
Prof. Christos Pyrgidis, Aristotle University of Thessaloniki, Greece
Prof. Carmen Racanel, Technical University of Bucharest, Romania
Prof. Stefano Ricci, University of Rome, Italy
Prof. Tatjana Rukavina, University of Zagreb, Croatia
Prof. Mirjana Tomičić–Torlaković, Univiversity of Belgrade, Serbia
Prof. Brigita Salaiova, Technical University of Kosice, Slovakia
Prof. Peter Veit, Graz University of Technology, Austria
Prof. Marijan Žura, University of Ljubljana, Slovenia

APPLICATION OF MULTICRITERIA ANALYSIS FOR SELECTION OF ALTERNATIVE IN THE ROAD PROJECTS

Aleksandar Glavinov[1], Zoran Krakutovski[2],
Slobodan Ognjenovic[2], Katerina Mitkovska–Trendova[1]
1 University Goce Delcev, Military Academy General Mihailo Apostolski,
Republic of Macedonia
2 University Sts. Cyril and Methodius, Faculty of Civil Engineering Skopje,
Republic of Macedonia

Abstract

The importance and public nature of road infrastructure requires involvement of many stakeholders in the process of decision making in the democratic societies. The usage of Multi–Criteria Analysis (MCA) is a pertinent tool in decision making when some of specific objectives are imperative to achieve. Besides, the road infrastructure is very important for the system of civil protection and defence for all countries. This work shows the methodology for definition of criteria and determination of weight for each criterion. The following six main criteria are assessed: traffic flow, impact of spatial plan, civil engineering criteria, economical and financial criteria, environmental criteria, criteria for defence and system of civil protection. More specific sub–criteria are defined in each group of main criteria. The questionnaire with a list of main and specific criteria is sent to several institutions and experts in the country to give their opinion thereon, or to estimate each main criterion (first step of weighting) as well as to assess each sub–criterion (second step of weighting). The results of the survey concerning measurement of the importance of each criterion are used to develop Multi–Criteria Analysis. The assessment of three variants of road infrastructure is calculated through three methods of MCA: Sum Weight Method (SWM), Analytic Hierarchy Process (AHP) and ELECTRE. The comparison and recommendation for usage of MCA and choice of the calculation method is also provided in this work.

Keywords: multi–criteria analysis, road infrastructure, criterion, weighting.

1 Introduction

The planning and the execution of the road infrastructure are complex projects which are of interest to many subjects. Speciallly itneresting is the theoretical investigation of decision making in road projects, arrangements of the space for the defense needs and the application of multiriteria analyses in the process of decision making for the road infrastructure projects. This paper deals with the methods of multicriteria decision making as assistance to the 'decision maker' to identify the best agreed solution. In addition the improved techniques to typify the priorities and incorporate them in the decision making analysis has been displayed. Analysis of the road infrastructure has been made and a methodology for multicriterai analysis application in decision making process related to the roads has been suggested.

2 Criteria for assessing the conditions of the state raod network including the defence needs and the civil protection system

Application of multicriteria analysis as a support in decision making when selecting projects related to the road infrastructure requires identification and consideration of the preferences of the concerned subjects in the decison making process. An assessment of the importance of the criteria in the decision making process for the road net related projects and by considering the defence needs has been made by the use of a questionnaire.
A sample involved in the qestionarrie has been taken by the ministries and the independent authorities of the government the highest level being the head of a sector, the higher education institutions, professors, distinguished experts and heads of advisory teams and logistics experts.
The questionnarie has been structured in two parts. The first part represents six basic criteria displayed in table 1.

Table 1 Basic criteria

Number	BASIC CRITERIA	Mark
1.	Traffic criteria	TC
2.	Spatial criteria	SC
3.	Design – bulding criteria	DBC
4.	Economic and financing criteria	EFC
5.	Environment related criteria	ERC
6.	Defence related criteria	DRC

The second part defines the subcriteria for each of the abovementioned basic criteria in the questions and the possible measures for them. Four subcriteria have been proposed for the traffic, three for the spatial ones, eight for the economic, four for the building one, six for the environment protection and six defence subcriteria.
Such prepared questions were distributed to the relevant subjects to give weighting coefficient to each criterion and subcriterion. Out of the 50 questionarries sent, 40 respondents were received (80% respondents).
From the obtained responses and the allocated weighting it could be noticed that they are in accordance with the scope of interest and the subjects' competencies that mark the given criteria in the questionnaire. In order to avoid allocation of 100% coefficient for a single criterion, the methodology for questionnaire filling contains a condition that the maximum allocation for a certain criterion shouldn't surpass 60%. With this limitation each interviewed subject (expert of certain area) besides the mark for the criteria should determine and give a preference for the other criteria from the list.
From the received results, it could be concluded that the highest mark i.e. weighting coefficient, the 40 respondents gave to the fourth critera i.e. 'the economic and financing criteria' and it is 26.10%, while the lowest weighting coefficient is 'building critera' and it is 6.20%. These results have been apllied into the next applicative example which illustrates the use of obtained data.

3 Applicative example

The considered example refers to three variants from a road project and it is necessary to determine the most desired variant solution. Needed data (weighting coefficient) of the criteria and the subcriteria will be taken from the marks given in the conducted questionnaire. For analysis the following methods will be used: Method for full aggregation of the final result which is the

- Weight Sum Method (WSM – Weight Sum Methode);
- Method of analytic hierarchy process (AHP – Analytic Hierarchy Process) and
- Method of partial aggregation or method ELECTRE 1.

Table 2 Multicriteria matrix

VARIANTS	Criteria						
	TC	SC	DBC		EFC	ERC	DRC
	Traffic intensity	Maximum skew/ slope of grade level	Investment expenses	Exploatation expences	Contamination of the atmosphere	Linking the populated places	Linking the defence directions
	T1 (AADT)	S1 (%)	DB1 (103 €)	DB2 (103 €)	EF1 (descriptive)	ER1 (descriptive)	D1 (descriptive)
Variant road 1	6210	3,010%	67,2	601,2	90%	80%	100%
Variant road 2	6910	3,200%	70,3	572,3	80%	100%	90%
Variant road 3	7020	3,400%	68,1	594,7	100%	90%	80%
Weighting coefficient	0,21	0,06	DB1 = 0,17 DB2 = 0,09 DB = 0,26		0,13	0,12	0,22

Chracteristics of the three variants for which a comparison of seven criteria should be conducted and a mark should be allocated for selection of an investment project are displayed in the table 2.

Total expenses in the exploatation are a sum of exploatation expenses of the vehicles, maintenance expenses, traffic accidents expenses and expenses from the time of traveling, discounted to the first year of exploatation. Weighting coefficients are obtained from the questionnaire conducted as part of this work.

3.1 Weight Sum Method (WSM)

Applied method for comparing the variants is with a sum of weighting values of the separate critera, i.e. by the method of a global sum. Since the values of each critera are expressed in the natural measuring units or descriptively and differ regarding the critera and in order to make the comparisons, the values of each criterion should be brought to a non dimensional size and to establish a non dimensional matrix, i.e. to start the procedures known as normalization of the measures of the critera. This normalization is carried out with different attributes assigned for each critera and each variant in a comparable size and at the same time the preference for each criteria is determined as to whether the most desired solution is the highest or lowest measuring value (Table 3).

Table 3 Non dimensional matrix according to WSM

Variant	Criteria						
	T1 (+)	S1 (-)	DB1 (-)	DB2 (-)	EF1 (+)	ER1 (+)	D1 (+)
1	0.8846	1	1	0.9519	0.900	0.800	1
2	0.9843	0.9406	0.9559	1	0.800	1	0.900
3	1	0.8853	0.9868	0.9623	1	0.900	0.800
Weight	0.21	0.06	0.17	0.09	0.13	0.12	0.22

Determination of the global result for each of the three variants is as follows:

- Variant one: $\Sigma W = 0.8846 \times 0.21 + 1.00 \times 0.06 + 1.00 \times 0.17 + 0.9519 \times 0.09 + 0.9000 \times 0.13 + 0.8000 \times 0.12 + 1.00 \times 0.22 = 0.937$
- Variant two: $\Sigma W = 0.9843 \times 0.21 + 0.9406 \times 0.06 + 0.9559 \times 0.17 + 1.00 \times 0.09 + 0.800 \times 0.13 + 1 \times 0.12 + 0.900 \times 0.22 = 0.934$
- Variant three: $\Sigma W = 1.00 \times 0.21 + 0.8853 \times 0.06 + 0.9868 \times 0.17 + 0.9623 \times 0.09 + 1.00 \times 0.13 + 0.90 \times 0.12 + 0.800 \times 0.22 = 0.931$

According to this calculation,the best valued variant is the variant B1, although the results from the calculations show a small difference in the summed result.

3.2 Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a method of multicriteria analysis which enables modelling of complex problems in the hierarchical structure which represents the relations among the critera, suibcritera and possible variants.
With this method, the weightnig coefficients are measured and allocated as ratio among the critera and not like assigned ones, i.e. assessed weighting coefficient for each critera. AHP is based on three basic principles: decomposition, comparative assessment or synthesis of priorities. Decomposition refers to establishing hierarchical branching. The principle of comparative assessment refers to the comparison of pairs of all possible combinations. Principle of synthesis comprises of multiplication of local priorities in a group with global priority.
The application of the AHP method over an exapmle will be represented for selection of one of the three variants of road with criteria out of which the economic criteria have been divided in two subcriteria or there are totally seven critera according to which the variants are valued. The best valued variant according to the AHP method has been shown in the table 8.
According to this calcuation, the best valued varaint is also variant B1. Only the difference in the obtained results is more evident than in the previous method SWM.

Table 4 Grades used in mutual comparison in AHP method

Intensity (significance)	Definition	Explanation
1	Indentical significance	Two variants are equally significant in relation to the goal
3	Medium significance	More desired variant
5	Important significance	Strongly desired variant
7	Very important significance	Absolutely confirmed more desired variant
9	Extreme significance	Extreme more desired variant with highest confirmation
Intensity of 2,4,6 and 8 can also be mentioned (Source: T.L. Saaty, The Analitytic Hierarchy Process, McGraw-Hill, (1980))		

Table 5 Weighting coefficient at a critera level according to the AHP method

Criteria comparison	(TC)	(SC)	(DBC)	(EFC)	(ERC)	(DRC)	Suma	medium value
TC	1.00	6.00	0.50	4.00	3.00	2.00	16.50	0.251
SC	0.17	1.00	0.14	0.33	0.50	0.20	2.34	0.036
DBC	2.00	7.00	1.00	5.00	4.00	3.00	22.00	0.334
EFC	0.25	3.00	0.20	1.00	2.00	0.25	6.70	0.102
ERC	0.33	2.00	0.25	0.50	1.00	0.33	4.42	0.067
DRC	0.50	5.00	0.33	4.00	3.00	1.00	13.83	0.210
	4.25	24.00	2.43	14.83	13.50	6.78	65.79	1.00

Table 6 Normalization of weight coefficient at a criteral level accroding to the AHP method

Criteria comparison	(TC)	(SC)	(DBC)	(EFC)	(ERC)	(DRC)	Suma	Weight coefficient
TC	0.24	0.25	0.21	0.27	0.22	0.29	1.48	0.246
SC	0.04	0.04	0.06	0.02	0.04	0.03	0.23	0.038
DBC	0.47	0.29	0.41	0.34	0.30	0.44	2.25	0.375
EFC	0.06	0.13	0.08	0.07	0.15	0.04	0.52	0.086
ERC	0.08	0.08	0.10	0.03	0.07	0.05	0.42	0.070
DRC	0.12	0.21	0.14	0.27	0.22	0.15	1.10	0.184
	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.000

Table 7 Calculation with combined pondering with weight coefficient according to the AHP method

Weight 1	**0.246**	**0.038**	**0.375**	**0.375**	**0.086**	**0.070**	**0.184**
	(TC)	**(SC)**	**(DBC)**		**(EFC)**	**(ERC)**	**(DRC)**
Weight 2	**-**	**-**	**0.67**	**0.33**	**-**	**-**	**-**
	AADT	Skew/ slope grade level	Investment expenses	Exploatation expenses	Atmosphere contamination	Linking populated places	Linking defence directions
B1	0.11	0.54	0.72	0.11	0.30	0.14	0.54
B2	0.26	0.30	0.08	0.63	0.16	0.62	0.30
B3	0.63	0.16	0.19	0.26	0.54	0.24	0.16

Weight 1	**0.246**	**0.038**	**0.375**	**0.375**	**0.086**	**0.070**	**0.184**
	(TC)	**(SC)**	**(DBC)**		**(EFC)**	**(ERC)**	**(DRC)**
Weight 2	**-**	**-**	**0.67**	**0.33**	**-**	**-**	**-**
	ПГДС	Skew/slope grade level	Investment expenses	Exploatation expenses	Atmosphere contamination	Linking populated places	Linking defence directions
B1	0.03	0.02	0.18	0.01	0.03	0.01	0.10
B2	0.06	0.01	0.02	0.08	0.01	0.04	0.05
B3	0.16	0.01	0.05	0.03	0.05	0.02	0.03

Table 8 The best valued variant according to the AHP method

FINAL RESULT		**RANKING**
B1	0.38	1
B2	0.29	3
B3	0.34	2
	1.00	

3.3 ELECTRE 1 – model for decision making with sequential classification

ELECTRE 1 (Elimination Et Choix Traduisant la Realité) is a method which enables to lead to subject which makes a decision in its choice of one possible activity (a) in the set A of activities knowing that many criteria of preferences should be considered from non aggregated characteristics of the possible activities. ELECTRE 1 is a method of divide in the presence of many criteria. More precisely, it is a method which enables bipartition in A, between the selected activity (i) and the other activities A-1 which are eliminated. So, this method uses the technique of comparision of each variant. By applying this variant the results is that the variant B1 dominates the other two variants and is the best valued variant.

4 Conclusion

Previously pointed methods for road infrastructure projects' assessment are applicable and should be part of a process for variants assesment. It is important to include all the intereseted subjects from the project in the project monitoring body which by its participation will contribute to the assesment of the most desired project. This research has considered a criterion which assesses the variances from the aspect of the defence needs.
The results show that the obtained global results from the evaluation of the three variances are very close. Therefore, analysis of the results' sensitivity when the input parameter for the variant attributes change should be made. One probability approach to determine the input parameters would be more objectively acceptable concept for multicritera analysis application.

References

[1] Koski, J (1985), 'Defectiveness of weighting method in multicriterion optimization of structures', Communication in Applied Numerical Methods, Vol. 1, Issue 6, pp. 333-337

[2] Saaty, T. L. (2006): 'Fundamentals of Decision Making and Priority Theory with he Analytic Hierarchy Process', Vol VI of the AHP Series, RWS Publications, 2006.

[3] Roy, B. and Figueira J., (1998): 'Détermination des poids des critères dans les methods de type ELECTRE avec la technique de Simos revise', Université de Paris-Dauphine, Doc. du LAMSADE n°109.

[4] Kim IY, de Weck OL (2005), Adaptive weighted sum method for bi-objective optimization: Pareto front generation, Struct MUltidiscipl Optim 29: 149-158

[5] Saaty, T. L., (2001): 'Decision Making For Leaders: The Analythic Hierarchy Process for Decisions in a Complex World'. RWS publications, Pittsburgh. 1990, new–edition.

[6] Roy, B. (1996): 'Les logiques compensatoires et les autres', in: Proceedings des 44émes Journées du Groupe de Travail Européen Aide Multicritére á la Décision, Bruxelles, Belgique.

[7] Roy, B., (1990): 'The out ranking approach and the found ations of ELECTRE methods'. In C.A. Banae Costa, editor, Readings in Multiple Criteria Decision Aid, pages 155-183. Springer-Verlag, Berlin.