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MULTI-CRITERIA OPTIMISATION OF THE PAN-EUROPEAN CORRIDOR V_B COMPETITIVENESS

ABSTRACT

Since possibilities of the traffic route valorisation need to be analyzed within market conditions, the traffic service of Pan-European corridor V_B, which is the subject of research in this paper, is analyzed from the viewpoint of the offer, demand and competitive surroundings. Corridor V_B, as vital transit route of the Republic of Croatia, is analyzed with an all-inclusive evaluation of selected economic and qualitative criteria relevant for the analysis of the traffic service competition. The suggested model for optimising the Pan-European corridor V_B competitiveness is justified in keeping with method principles of multi-criteria optimisation. Among many different processes of multi-criteria optimisation, in the research PROMETHEE method and computer program Promcalc & Gaia V.3.2., which is based on the mentioned method, were used.

KEY WORDS

Pan-European corridor V_B, multi-criteria optimisation, PROMETHEE method

1. INTRODUCTION

Valorisation of the traffic route is a complex problem, which has to take into consideration many different elements. In keeping with this, Pan-European corridor V_B (Rijeka- Zagreb - Budapest), which is a vital transit route of the Republic of Croatia and the subject of this research, is considered and analyzed including the European transit market, alternative transport routes and relevant economic and quality criteria. With regard to the fact that all these elements determine the traffic route competitiveness and position on the transport market, the main goal of this research is to suggest the model of multi-criteria optimisation of the Pan-European corridor V_B, which also could be used and applied as a methodology for analysis of any other transport route competitiveness.

The suggested model is justified in keeping with method principles of multi-criteria optimisation, which is included in operation research methods and it represents the process of multi-criteria optimisation of variants. Among many different processes of multi-criteria optimisation, PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) and Promcalc & Gaia V. 3.2., a computer program of multi-criteria programming which is based on the mentioned process, were used.

On the basis of exact quantitative information and evaluation, a value of selected economic and qualitative criteria, has been put into effect. The mentioned information together with defined traffic (competitive) routes and the users' preferences are used as basic input elements of the suggested model. In keeping with the primary goal of the research, the received results give conclusions about the competition, that is non-competition of Pan-European corridor V_B with regard to alternative traffic routes, despising among many analyzed economic (quantitative) and qualitative criteria those criteria which are at the moment responsible for its presence, that is non-presence on the traffic service market and those criteria that could give higher competition to this traffic route with certain investments.

2. PAN-EUROPEAN CORRIDOR V_B – VITAL TRANSIT ROUTE FOR THE REPUBLIC OF CROATIA

Pan-European corridor V_B (transversal link between Rijeka – Zagreb – Budapest) was proclaimed an official Pan-European corridor at the Third Pan-Eu-

ropean Conference of the European Ministers of traffic, held on June 1997. Therefore, a prerequisite was satisfied for valorising the favourable location and meaning that Croatia has in the European traffic system in terms of general European interest as well as the interest of Central Europe and the Danube region.

The traffic significance of Corridor V_B, that integrates the capital traffic infrastructure in the Republic of Croatia, lies in its importance for connecting Central European, Pannonian and Baltic areas with Eastern Europe, through the port of Rijeka. Therefore, the Adriatic region is connected with Corridor V_B in the narrow and the Mediterranean in the broader sense. The significance of Corridor V_B for the economy in the Republic of Croatia is confirmed by the fact that one half of the total Croatian foreign trade is done with the European countries in the proximity of the port of Rijeka and Rijeka traffic corridor branch (Italy, Germany, Slovenia, Austria, Bosnia and Herzegovina and Hungary). Should Croatia's foreign partner states that have their own ports or are closer to other European ports be exempted, then Corridor V_B has very high significance in maritime trade of Central European countries (Austria, the Czech Republic, Slovakia, Hungary and Bosnia and Herzegovina). The reference point of Corridor V_B is the port of Rijeka that has particular international importance for the Republic of Croatia. Its importance is visible in the value of the port services provided in respect of the total Croatian economy (HRK 4-5 million per day)[1], including the multiplication effect achieved by engaging other logistic subjects (road transport, railway, freight forwarders, agents...).

With 67% share, the transit traffic of the port of Rijeka is the most important segment in total traffic. The main partners of the port of Rijeka are Austria, the Czech Republic, Slovakia, Hungary and Italy, and nowadays Bosnia and Herzegovina as well as Serbia and Montenegro[2]. Considering that transit traffic is very important to every port and corridor, and therefore also for the traffic of Rijeka, it is prerequisite to create the environment for transit loads competitive acquisition of the main Central European countries as main transit partners for the port of Rijeka. According to the above stated, competitive and strategic guidelines for Corridor V_B valorisation should be conceived from the point of demand, supply and surrounding.

Traffic corridor supply is determined by specific attributes of road, railway and maritime traffic as well as ports, inland waterways that include many criteria and logistic principles of maritime services competitiveness. In that sense, this paper takes economic and qualitative criteria regarding competitiveness of traffic services in consideration. The marketplace determines the traffic service, consumers therefore outlining the demand specificity. From the surroundings point of view, it is necessary to stress the competitiveness on valuable transit services market of Corridor V_B. Not diminishing the competitiveness of other traffic corridors from the North European ports (Corridors X, IV and VII) and competitiveness of ports in Montenegro (Corridor VII), this paper will consider as competitive corridors to Corridor V_B those from other North Adriatic ports (Koper and Trieste) since those two are the closest competition to Corridor V_B on Central European transit marketplace.

3. THEORETICAL DETERMINATION OF MULTI-CRITERIA OPTIMISATION

The complexity of planning the competitiveness of traffic corridor indicates the need for appropriate methodology in order to simplify the procedure of planning the valorisation of traffic corridor. Therefore, this part analyzes the multi-criteria optimisation model being a method that can be applied in traffic corridor planning valorisation as well as complex traffic phenomena in general.

3.1. Multi-criteria optimisation

The goal of optimisation is to choose the best option out of possible or favourable options in terms of accepted criteria. Such option is called optimal variant and optimal solution that derives from compromise of goals and possibilities, goal achievement and limitations.[3] General characteristics of multi-criteria problem, unlike single criteria problem, are: multiple criteria for decision-making, multiple alternatives (solutions) to choose from, and one solution selection process.

The optimal choice of solution is a problem that becomes very complex if there are many criteria according to which optimal solution is to be determined. Such problems can be solved by multi-criteria optimisation. The quality of procedure of choosing the best variant and accuracy of final decision will depend upon the quality of criteria determination and its measuring in respect to the optimisation process. Variant generation analyzes all possible solutions of the problem, selects reasonable set which represents the number of variants within which final variant will be chosen from.

The decision-maker has the crucial role in the procedure of multi-criteria optimisation model and quality variant definition. As legal entity or natural person responsible for decision-making and adoption of final solution, the basic role that decision-maker plays is defining the preferences of criteria and structure as well as choosing and adopting the final solution. The com-

plexity of decision-making process lies in the preference structure of the decision-maker that is based upon technical, technological, economic, social, political and other criteria that can be known prior to optimisation or can be changed after completion of certain optimisation processes.

3.2. Multi-criteria variant ranking process

Multi-criteria ranking process is one of the many processes of multi-criteria optimisation method, that are used with the purpose of setting up the rank lists of variant solutions based upon the degree of defined criteria satisfaction. The purpose of variant ranking is to narrow the decision gap and to quantify the facts that are important for decision-making process and for optimal variant choice from the set of variants that differ depending on the adopted criteria.

The basic prerequisites for multi-criteria variant ranking process quality are the following:

- all variants have to be defined at the same level, same criteria has to be applied to all variants;
- criteria has to be carefully chosen and their difficulty must be objectively estimated;
- all variants have to be valued according to the criteria adopted.

Multiple ranking procedures can be based upon the processes with in-advance expressed preferences such as: PROMETHEE (Preference Ranking Organization Method), ELECTRE (Elimination and (et) Choice Translating Reality) and AHP (Analitic Hierarchy Process), processes for sets of non-inferior solutions like IKOR or other processes of multi-criteria optimisation for variant ranking: PROMETHEE, ELECTRE and AHP, where PROMETHEE and ELECTRE belong to "higher rank" processes and AHP to the "priority" process. For the purpose of this research in this paper PROMETHEE method , and computer program Promcalc & Giaia V. 3.2. (newer version - Decision Lab 2000 - for Windows) developed on the basis of the mentioned method were used.

4. MULTI-CRITERIA OPTIMISATION MODEL SUGGESTION FOR COMPETITIVENESS OPTIMISATION OF PAN-EUROPEAN CORRIDOR V_B

According to the basic multi-criteria variant ranking procedure, for this model and with input of data into computer program used, the variants (competitive traffic corridors), competitiveness criteria of traffic service, combinations, criteria complexity (criteria significance from consumer aspect) and optimal criteria size (minimum or maximum criteria value) had to be determined. Criteria valuation was then conducted for all the chosen variations. Assessment of the above stated data have been input into computer software PROMCALC & GIAIA V. 3.2. which resulted in multi-criteria optimisation (variant ranking of traffic corridors analyzed).

4.1. Multi-criteria optimisation based on PROMETHEE II method

In the paper the authors have selected those corridors (generated variants) that are currently significant for Central Europe, and from the set of possible combinations (alternative corridors), a few of the variants that satisfy the criteria have been also selected. Variants that have been taken into consideration in this research are shown in Table 1, and relate to traffic routes from Rijeka, Koper and Trieste that represents the reference points of every traffic corridor, to its destination – capital cities of Central European transit countries (Austria, Czech Republic, Slovakia and Hungary).

Table1 - Variants of traffic routes

Variants A	Variant A1:	port of Rijeka – Austria (Vienna)
	Variant A2:	port of Koper – Austria (Vienna)
	Variant A3:	port of Trieste– Austria (Vienna)
Variants B	Variant B1:	port of Rijeka – Czech (Prague)
	Variant B2:	port of Koper – Czech (Prague)
	Variant B3:	port of Trieste– Czech (Prague)
Variants C	Variant C1:	port of Rijeka – Slovakia (Bratislava)
	Variant C2:	port of Koper – Slovakia (Bratislava)
	Variant C3:	port of Trieste – Slovakia (Bratislava)
Variants D	Variant D1:	port of Rijeka – Hungary (Budapest)
	Variant D2:	port of Koper - Hungary (Budapest)
	Variant D3:	port of Trieste – Hungary (Budapest)

The variants are divided into four groups (A, B, C and D) and competitive analyses will be conducted for each variant group in order to determine the optimal traffic corridor and port as transit point for certain destination points for Central Europe. Multi-criteria

Table 2 - Types and measures of economic criteria

Crite-rion	Sub Criterion	Mark	Component	Mark	Measure			
K1	Economic	pk11	Costs in Ports / Ship	CP-V	k11.1	Light Dues	LD	euro
					k11.2	Port Dues	PD	euro
					k11.3	Pilotage	P	euro
					k11.4	Mooring / Unmooring	M/UN	euro
					k11.5	Customs Dues	CD	euro
					k11.6	Agency Fee	AF	euro
					k11.7	Garbage Removal	GR	euro
					k11.8	Towage	T	euro
					k11.9	Other	O	euro
					k11.10	Total costs/Ship (k11.1+...+k11.10)	TC-V	euro
		pk12	Costs in Ports / Cargo	CP-C	k12.1	Unloading (Ship – terminal)	U	euro/20'TEU
					k12.2	Loading (terminal - vehicle)	L	euro/20'TEU
					k12.3	Total costs / Cargo (k12.1+k12.2.)	TC-C	euro/20'TEU
		pk13	Price -Inland Transport	TP-IT	k13.1	Price of road transport	P-RT	euro/20'TEU
					k13.2	Price of railway transport	P-RT	euro/20'TEU
		pk13	Total Price - Transport Service	TP-TS	k13.1	Port Dues + Price of road transport (k12.3+k13.1)	PD-RD	euro/20'TEU
					k13.2	Port Dues + Price of railway transport (k12.3+k13.2)	PD-RW	euro/20'TEU

Source: Authors

analysis of the generated variations was conducted for three cases:

- Road traffic corridor variant,
- Railway traffic corridor variant, and
- Road and railway traffic corridor variant.

Cases with certain difficulty level combination that are to be taken into consideration were also analyzed. For example, in. case I, criteria applied to the analyzed ports and road traffic corridors will hold certain weight assigned to it, while in the criteria case that applies to railway corridor the criteria difficulty that equals zero will hold. Pursuant to the above stated, the appropriate difficulty value combinations were set and entered into software for other two cases. This paper considers *Quality-Price-Ratio* as criterion of traffic corridor competitiveness. Therefore, the defined criteria subject to valuation are: economic criteria (Table 2) and qualitative criteria (Table 3).

The selected criteria are valued simultaneously for all the defined variants (Table 1) and represent the basic input data of multi-criteria analysis for Corridor V_B valorisation optimisation. Depending upon the criteria type, certain criteria were valued based upon concrete (exact) data, and some based upon subjective assessment but with argument for grades assigned to it. Such comparison possibility of differently dimensioned criteria is also one of the advantages of multi-criteria optimisation model.

The basic part of research plan and one of the prerequisites for multi-criteria model analysis is determining the combination of selected criteria, criteria difficulty and criteria function, and which changes of criteria have impact on the optimal solution selection (variant is visible). Criteria difficulty was the significance of certain criteria and multi-criteria method valued are the following: difficulty 0 – criterion is taken into consideration; difficulty 1 – small criteria difficulty; difficulty 2 – medium criteria difficulty; difficulty 3 – high criteria difficulty.

According to the basic PROMETHEE principles, it should be noted that all valuation criteria were defined as Type 1 (general criteria) – a criterion that does not require additional parameters for preference function specification.

4.2. Multi-criteria optimisation results

According to the goal of this research, the main output data that will be analyzed and based upon significant conclusions can be defined regarding Corri-

Table 3 - Types and measures of quality criteria chosen

Crite-rion	Sub Criterion	Mark	Component	Mark	Measure			
K-2	Quality	pk21	Transit Time	TV	k21.1	Transit time - road transport	TT-RD	hour
					K21.2	Transit time - railway transport	TT-RW	hour
					k21.3	Waiting time on borders – road transport	WT- RD	hour
					K21.4.	Waiting time on borders – railway transport	WT- RW	hour
					k21.5	Total time of travelling – road transport (k21.1+k21.3)	T-TRD	hour
					k21.6	Total time of travelling –railway transport (k21.2+k21.3)	T-TRW	hour
		pk22	Geotraffic Availability	GP-D	k22.1	Road distance	D-RD	km
					k22.2	Railway distance	D-RW	km
		pk23	Commercial Availability	K-D	k23.1	Availability of road terminals	A-RDT	number
					k23.2	Availability of railway terminals	A-RWT	number
					k23.3	Availability of cargo transport canters	A-CTC	number
		pk24	Service Frequency	F	k24.1	Shipping lines (number of shippers)	S-L	number
					k24.2	Railway lines (container block trains)	RW-L	criticism
		pk25	Capacities	PK	k25.1	Port capacities	C-P	criticism
					k25.2	Road transport (organisation road forwarding)	O-RD	criticism
					k25.3	Railway transport (organisation of railway forwarding)	O-RW	criticism
					k25.4	Road capacities	C-RD	criticism
					k25.5	Railway capacities	C-RW	criticism
		pk26	Information Technology	IT	k26.1	IT implementation in ports	IT-P	criticism

Source: Authors

dor V_B competitiveness by traffic corridor analysis. Value ranking has been conducted in regard to:

- economic criteria influence,
- quantitative criteria influence and
- combination of the above stated criteria influence.

In variant ranking, the rank number equals the number of variants. According to that, in this research, where total variant number is 3 (per group), ranks from 1 to 3 are possible, where at rank 1 the variant is the best one (optimal) to certain criteria, rank 3 – less favourable variant in regard to the other two. Multi-criteria optimisation method results (ranks) where variants of traffic corridors are shown are presented in Tables 4 and 5. Table 4 shows traffic corridor variant ranking, separate for economic criteria and for qualitative criteria, and Table 5 shows variant ranking according to the simultaneous influence of economic and quantitative criteria.

Results obtained with multi-criteria optimisation models may be used as background for decision-making of optimal traffic corridor (variant). For example, when decision has to be made regarding which traffic corridor is optimal, the best variant is one ranking first, and the worst is the one ranking last. Prerequisite for this is to define mutual difficulty criteria ratios. With multi-criteria optimisation model results it can be concluded that road and railway routes of Corridor V_B are increasing their competitiveness according to the analyzed destinations with regard to economic criteria and not according to the qualitative criteria. In accordance to the above stated, the priority measures concerning Corridor V_B valorisation should be the ones concerning activities of increasing the traffic service quality. On the contrary, railway route is more competitive in comparison to road route in respect to economic and qualitative criteria.

Table 4 - Variant ranking list – special influence of economic and qualitative criteria (PROMETHEE II)

Criteria		Economic & Quality Criteria		
Routes		Road	Rail	Road and Rail
A - Variants				
Rank	1.	A2	A3	A2
	2.	A3	A2	A3
	3.	A1	A1	A1
B - Variants				
Rank	1.	B3	B2	B2
	2.	B2	B3	B3
	3.	B1	B1	B1
C - Variants				
Rank	1.	C3	C3	C3
	2.	C2	C2	C2
	3.	C1	C1	C1
D – Variants				
Rank	1.	D3	D3	D3
	2.	D2	D2	D2
	3.	D1	D1	D1

Source: Results from data processing using program PROMCALC & GIAIA V. 3.2. - PROMETHEE II

Table 5 - Variant ranking list – simultaneous influence of economic and qualitative criteria (PROMETHEE II)

Criteria		Economic Criteria			Quality Criteria		
Routes		Road	Rail	Road and Rail	Road	Rail	Road and Rail
A - Variants							
Rank	1.	A2	A3	A2	A3	A2	A3
	2.	A1	A2	A3	A2	A3	A2
	3.	A3	A1	A1	A1	A1	A1
B - Variants							
Rank	1.	B2	B1	B2	B3	B3	B3
	2.	B3	B2	B1	B2	B2	B2
	3.	B1	B3	B3	B1	B1	B1
C - Variants							
Rank	1.	C2	C1	C2	C3	C3	C3
	2.	C1	C2	C1	C2	C2	C2
	3.	C3	C3	C3	C1	C1	C1
D – Variants							
Rank	1.	D2	D1	D2	D3	D3	D3
	2.	D1	D2	D1	D2	D2	D2
	3.	D3	D3	D3	D1	D1	D1

Source: Results from data processing using program PROMCALC & GIAIA V. 3.2. - PROMETHEE II

However, because of the size of this paper and limitations attributed to such, only general conclusion has been pointed out. Detailed analysis provides much more precise conclusions regarding competitiveness (or lack thereof) of Corridor V_B in comparison to alternative corridors. However, with detail variant analysis, assuming the result tracking with different criteria significance, it is possible to specify those criteria that are currently responsible for its presence (or lack thereof) at the traffic service marketplace.

5. CONCLUSION

One of the modern methods that at the same time take into account the analysis of different criteria is multi-criteria optimisation. Although the above stated method, as support in decision-making can be applied to several areas, limitations have been spotted while using it for traffic planning. This paper encloses the multi-criteria optimisation model for achieving competitiveness of the Pan-European corridor V_B. The above stated model has a goal to show that with applying the multi-criteria optimisation, conclusions can be derived regarding the competitiveness (or lack thereof) of traffic corridor on the traffic service marketplace as well as conclusions regarding the factors for competitiveness, measures and activities that need to be undertaken in order to revitalize those corridors to match the competitive surroundings.

Besides a concrete problem being applied (Corridor V_B), the value of the suggested model is also visible in the methodology offered. The specific methodology applied is multi-criteria analysis that has in this paper been only partially shown, but it is possible to use it in general traffic planning. The multi-criteria analysis model applied in traffic corridor valorisation can be perfected having the complexity of competitiveness and valorisation of traffic corridors in mind. In other words, Pan-European corridor V_B valorisation in European traffic system has been analyzed in this paper considering the criteria selected and certain alternative traffic corridors which does not exclude the possibility of in-depth analysis considering the greater number of alternative traffic corridors and competitiveness criteria, considering the gravitation area and potential marketplaces of Rijeka traffic system.

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SAŽETAK

VIŠEKRITERIJSKA OPTIMIZACIJA KONKURENTNOSTI PANEUROPSKOG KORIDORA V_B

Budući da je konkurentnost prometnog pravca potrebno analizirati s obzirom na tržišne uvjete, prometna usluga paneuropskog koridora V_B, koji je predmetom istraživanja u ovom radu, analiziran je s aspekta ponude, potražnje i konkurentnog okruženja. Koridor V_B, analiziran je detaljnom analizom odabranih ekonomskih i kvalitativnih kriterija relevantnih u analizi konkurentnosti prometne usluge. Predloženi model optimizacije konkurentnosti paneuropskog koridora V_B osmišljen je u skladu s temeljnim principima metode višekriterijske optimizacije. Između više različitih postupaka višekriterijske optimizacije, u istraživanju je korištena metoda PROMETHEE te računalni program Promcalc & Gaia V.3.2., koji se temelji na navedenoj metodi.

KLJUČNE RIJEČI

Paneuropski koridor V_B, višekriterijska optimizacija, metoda PROMETHEE.

REFERENCES

1. Novi list, 10 Sept. 2004.
2. *Statističko izvješće*, Luka Rijeka, 2004.
3. **Nikolić, I., S., Borović**, *Višekriterijumska optimizacija - metode, primjena, softver*, Dio I, Beograd, Centar vojnih škola vojske Jugoslavije, 1996., p. 6.
4. *Efficiency and Quality, Thematic Synthesis of Transport Research results*, European Commission Transport RTD Programme, Fourth Framework Programme, 6/22, October, 2001.

LITERATURE

[1] **Brans, J. P., Vinche**, *Preference Ranking Organisation Methods: The Promethee Method for MCDM*, Management Science, 13 (1985)
[3] **Karleuša, B., A., Deluka-Tibljaš, M., Benigar**, *Mogućnosti primjene postupaka višekriterijske optimizacije u prometnom planiranju i projektiranju*, Suvremeni promet, 23 (2003), 1-2
[5] **Nikolić, I., S., Borović**, *Višekriterijumska optimizacija – metode, primjena, softver*, Dio I, Beograd, Centar vojnih škola vojske Jugoslavije, 1996.
[6] **Pađen, J.**, *Metode prostorno-prometnog planiranja*, Informator, Zagreb, 1978.
[7] **Poletan, T., H., Baričević**, *Integralni pristup u analizi kopnene prometne povezanosti luke Rijeka sa zaleđem*, Pomorstvo, 16 (2002)
[9] **Roy, B., P., Vinche, B., Mareschal**, *How to Select and How to Rank Project: The PROMETHEE Method*, European Journal of Operational Research, br. 24 (1981),
[11] *Transport Infrastructure Regional Study in the Balkans -TIRS, Final Report*, European Conference of Ministers of Transport - ECMT, March 2002.