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ECONOMIC EVALUATION AND SELECTION OF ROUTE FOR NEW RAILWAY ZAGREB-RIJEKA

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Abstract

National program of railway infrastructure in period 2008–2012 put the goal on modernization and construction of modern infrastructure network in pan European corridors inside the territory of Republic Croatia. Railway from Botovo (state border with Hungary) to Rijeka via Zagreb and Karlovac is financial complex task which is anticipate in National program on pan European corridor Vb Budapest – Rijeka. Existing railway on this corridor cannot meet standards of modern rail, so a new railway is planed. Several routes of new railway are set up by technical, technological and traffic conditions. Economic evaluation of these routes is done by Method of internal rate of return and Sensitivity analyze. If these routes are analyzed only in profitability means, the environment conditions are neglected. In order to find route (or routes) that fulfil economic and environment conditions, even they are in conflict, multictireria method is applied. The results of economic evaluation and results of environment study make basis (input data) for route selection. This paper presents the methodology for evaluating the railway routes considering all parameters related to rail project.

Keywords: new railway, economic evaluation, route selection, multicriteria analysis

1 Introduction

Part of pan European corridor Vb is in direction from Zagreb to Rijeka. Existing railway on this corridor was planed and built in 19th century and it could not fulfil modern rail traffic conditions. Even reconstruction and modernization cannot meet standards of modern rail. Therefore, a new railway route is planed.

Functional transport system incorporates new railway, transport network of Rijeka (railway and cargo ports) and transport network of Zagreb. Rational investment means harmonization of new railway construction with reconstruction and modernization of two transport networks and Rijeka cargo port. The rail transportation demand requires reorganization of existing railway station Krasica (near Rijeka) and Hrvatski Leskovac (near Zagreb). Two mentioned railway stations are the end-points of new railway route. The railway link from Krasica to Rijeka will be defined in next phases of route planning (the railway link from Zagrem to Hrvatski Leskovac existed).

This paper intends to present a methodology for economic evaluation and route selection, so, only the new planned railway on Vb corridor from Zagreb to Rijeka is taken into the consideration.

2 Economic evaluation

Input data for economic evaluation are technical, technological and traffic conditions and construction costs. They are defined for all variants of railway route [1] and illustrated on Figure 1.

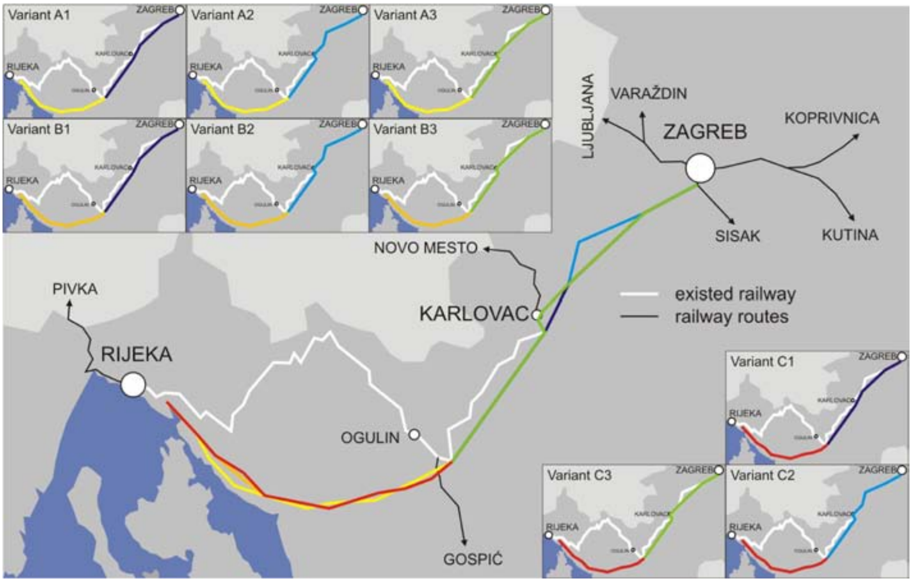

Figure 1 Variants of new railway, [1]

A usual method for survey of investment profitability is Method of internal rate of return [2] that could be shortly described by formula:

$$NPV(i) = 0 \Rightarrow IRR = i \quad (1)$$

Condition on Eq. (1)

$$IRR > 5\% \quad (2)$$

Variables in Eq. (1) are: *NPV* is net present value; *i* is interest rate; *IRR* is internal rate of return. Recommended value of interest rate of 5% [3] determines the lowest value that *IRR* should not meet, Eq. (2). The planning period is 30 years.

The NPV consists of present value of all benefits, present value of all operational cost, present value of construction costs (defined in [1]), salvage value (the value of project at the end of planning period, [4]).

Comparing situation "with new railway" with situation "without new railway", the difference between the operation costs "with" and "without" new railway is considered as benefit. During the planning period this benefit increases linearly with increase of traffic. Its present value (PB) is calculated according to formula:

$$PB = B_1 \cdot f \quad (3)$$

Variables in Eq. (3) are: B_1 is difference between the operation costs "with" and "without" new railway of the first year; *f* is a ratio that depends on rate of traffic increase, interest rate and number of years in planning period [2].

Operation costs (of existing and new railway) are calculated as unit cost of transport by rail (per gross tones kilometres). Operation cost should be calculated for cargo traffic and for

passenger traffic. During the planning period, operation costs increase linearly with increase of cargo traffic (at rate of 7,22%, [5]) and passenger traffic (at rate of 3,44%, [5]).
Economic evaluation takes into account: 1) interest of Railway Company that leads to **financial analyze**; 2) interest of community that leads to **economic analyze**.
Financial analyze identifies and quantifies: benefit of cargo and passenger rail transport cost decreasing; benefit of increased rail transport capacity; benefit of long-distance rail passenger traffic; benefit of transport volume increase on railway network; benefit of increased transit cargo traffic.
Economic analyze identifies and quantifies: benefit of cargo and passenger rail transport cost decreasing; benefit of redirection of cargo and passenger traffic from road to rail; benefit of travel time reduction; benefit of transport time reduction; benefit of long-distance rail passenger traffic; benefit of transport volume increase on railway network. Economic analyze does not take into account new railway infrastructure depreciation in order to avoid double calculation of the same values, since infrastructure cost is of part construction cost.
Economic evaluation of new railway is done by applying Eq. (1) to Eq. (3) on all variants. The result of economic evaluation is financial internal rate of return (FIRR) and economic internal rate of return (EIRR).
Sensitivity analyze shows how cost and benefit changes will affect financial internal rate of return and economic internal rate of return. Increasing of cost with percentage of 10% and 20% [6] and decreasing of benefits with percentage of 10%, 20%, 30 % [6] is analyzed.
The results of economic evaluation and sensitivity analyze are shown in Table 1 and in Table 2. Values in bold font (black and purple) in each table present applying of Eq. (2) on results of sensitivity analyze.

Table 1 Sensitivity analyze – FIRR

VARIJANTE	A1	A2	A3	B1	B2	B3	C1	C2	C3
FIRR (%)	4,93	4,80	4,89	5,13	4,93	5,02	5,29	5,17	5,25
Increase of costs									
+20	4,26	4,15	4,22	4,44	4,27	4,34	4,57	4,47	4,54
+10	4,58	4,46	4,53	4,76	4,58	4,65	4,91	4,80	4,87
Decrease of benefits									
-10	4,56	4,45	4,52	4,75	4,57	4,64	4,89	4,79	4,86
-20	4,18	4,07	4,14	4,35	4,19	4,25	4,49	4,39 %	4,46
-30	3,68	3,59	3,65	3,84	3,69	3,75	3,95	3,87 %	3,92

Table 2 Sensitivity analyze – EIRR

VARIJANTE	A1	A2	A3	B1	B2	B3	C1	C2	C3
EIRR (%)	**5,38**	**5,24**	**5,33**	**5,60**	**5,39**	**5,48**	**5,77**	**5,65**	**5,74**
Increase of costs									
+20	4,68	4,55	4,63	4,87	4,68	4,76	5,02	4,91	4,98
+10	5,01	4,88	4,96	5,21	5,01	5,09	5,37	5,25	5,33
Decrease of benefits									
-10	4,99	4,86	4,94	5,19	4,99	5,08	5,35	5,24	5,32
-20	4,58	4,46	4,54	4,77	4,58	4,66	4,91	4,80	4,88
-30	4,15	4,04	4,11	4,32	4,15	4,22	4,45	4,35	4,42

Comparison of results shown in Table 1 and Table 2 indicates that variant C1 has the highest financial internal rate of return and the highest economic internal rate of return.

Also, it is obvious that all variants are similar. Namely, the results of economic evaluation (FIRR in Table 1, EIRR in Table 2) make an interval of about 1,7% in length. Economic evaluation takes into consideration economic parameters. It is important to analyze parameters of environment in which new railway is incorporated, too. Multicriteria methods help to take economic and environmental parameters related to rail project.

3 Selection of the new railway route

Multicriteria methods assist in procedure of new railway route selection. The chosen method is PROMETHEE [7].
For purpose of railway route selection evaluation of nine variants (Fig. 1) is done by using economic criteria and engineering geological and ecological criteria as environment criteria (nine criteria in total).
Group of economic criteria consists of: *Construction costs* that are defined in designing project [1]; *Internal rate of return (IRR)* which values are calculated in Section 2; *Return period of investment* which values are calculated for all variants according to NPV(i) = 0 with interest rate of 5% [5].
Group of engineering geological criteria is represented by two criteria: *Seismic activity* and *Geological and tectonic conditions*.
Group of ecological criteria is represented by four criteria: *Impact on water; Rail traffic hazard; Costs of "Green objects"; Costs of noise decrease*.
Group of engineering geological criteria and Group of ecological criteria are defined by experts in geology and environment field [8].
Table 3 shows value and expert appraisals [8] for all variants together with rank and measure units. Weights are given for all parameters in two scenarios.
In scenario S1 (Table 3) high weight factor is given to *Group of economic criteria*, that will lead to selection of low cost variant (or variants).
In scenario S2 (Table 3) high weight factor is given to *Group of ecological criteria* that will lead to selection of ecology friendly variant (or variants).
Rank of variants according to scenario S1 is presented on Figure 2 and rank of variants according to scenario S2 is presented on Figure 3.

Table 3 Input data for PROMETHEE method

CriteriA	variants										S1	S2
(with brief description when is necessary)	A1	A2	A3	B1	B2	B3	C1	C2	C3			
Group of economic criteria												
1. *Construction costs* (10^3 €)	2735,10	2598,03	2601,11	2484,57	2347,50	2350,58	2464,60	2327,52	2330,60	min	25	15
2. *Internal rate of return IRR* (%)	4,93	4,80	4,89	5,13	4,93	5,02	5,29	5,17	5,25	max	20	13
3. *Return period of investment* (years) is calculated with interest of 5% for all variants	35,304	35,186	35,295	35,638	35,312	35,422	35,758	35,645	35,804	min	15	12
Group of engineering geological criteria [8]												
4. *Seismic activity* (km) The longest route length trough the zone of the lowest seismic activity (one zone for each degree of seismic activity)	82,64	85,82	97,37	79,74	82,92	94,47	81,74	84,92	96,47	max	6	9
5. *Geological and tectonic conditions* (estimate from 1 to 6)	4	4	4	3	3	3	2	2	2	min	5	6
Group of ecologic criteria [8]												
6. *Impact on water* (from estimate 1 to 6) Croatian low protects any kind of water (ground level water and underground water regardless of use for drinking)	4	4	3	5	5	4	3	3	2	max	4	7
7. *Rail traffic hazard* (km) The shortest route length trough the lowest zone of risks. The three zones of risk are: zone of high risk, zone of medium and zone of low risk.	31,60	31,61	62,07	31,60	31,36	62,07	31,60	31,61	62,07	min	7	10
8. *Costs of "green objects"* * (in €)	1,25	2,82	2,25	1,36	2,93	2,36	1,06	2,63	2,06	min	10	15
9. *Costs of noise mitigation* (in €)	1,24	1,79	1,37	1,30	1,85	1,44	1,05	1,60	1,19	min	8	13

* Objects that allow animal free pass over the railway and objects that stop animals to "step on" track

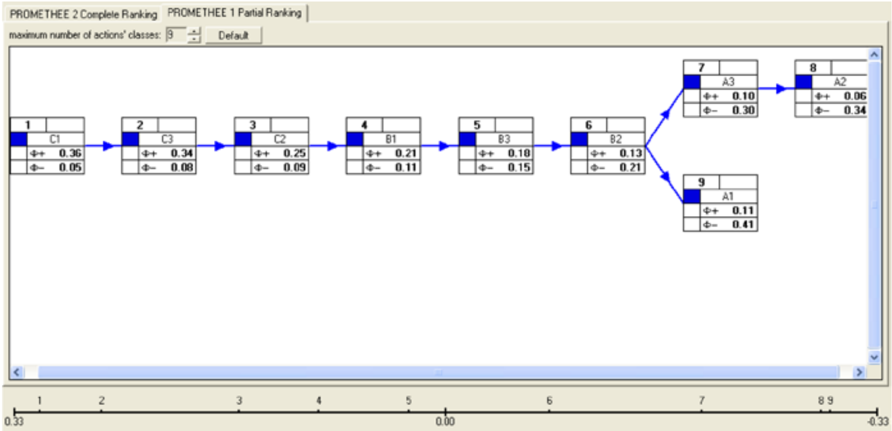

Figure 2 Analyze PROMETHEE – scenario S1

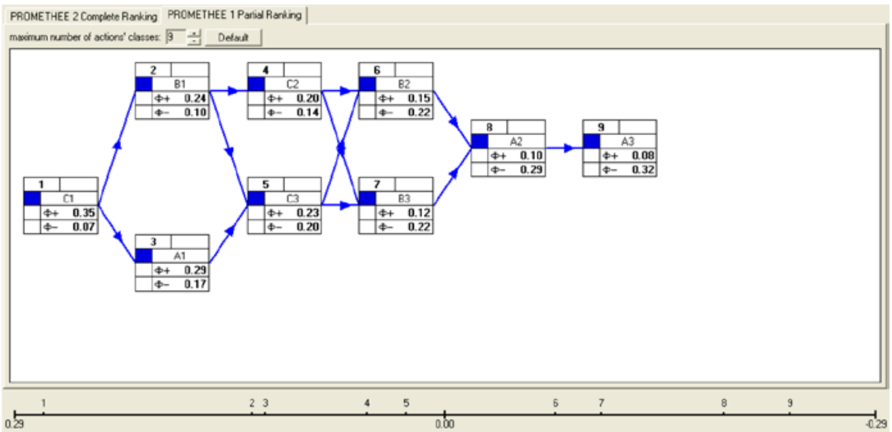

Figure 3 Analyze PROMETHEE – scenario S2

The scenario S1 rank results (Fig. 2) show that the most favourable variant is C1. It is followed by variant C3. Variants C1, C3 and C2 have advantage over other variants.
The change of weights in scenario S2 (Fig. 3) shows that the most favourable variant is C1, again. But in scenario S2, variant C1 has grater advantage over other variants then in scenario S1. Analyze of both scenarios shows that variant C1 meets the objectives described by economic and ecologic criteria.

4 Conclusion

New railway in pan European corridor Vb trough territory of Republic of Croatia (from Zagreb to Rijeka) is capital investment. It should have economic appraisal as a part of complex program of unique traffic service with modal diversion in corridor from Zagreb to Rijeka.
But, this paper intends to present methodology for railway evaluation, so only new railway from Zagreb to Rijeka is analyzed.
The brief description of presented methodology is: *Economic evaluation* point out the benefits of new railway construction and operation, not only for railway company but also for society; *Sensitivity analyze* varies the costs and benefits (as input) in order to test the stability of IRR

(as outcome) in financial and economic analyze; *Selection of railway route* with *multicriteria method* point out variant (or variants) that fulfil the objectives described by criteria.
Taking into account economical, engineering geological and ecological criteria, one variant (or several variants) has (or have) advantage over the other variants. In the case presented in paper, variant C1 has advantage over the other variants and has chance to be realized.
However, it should be emphasized that evaluation methodology helps in rationalization of route selection procedure. The result of evaluation and selection should help in next phases of new railway planning.

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