



HIGH PERFORMANCE RAILWAY CONSTRUCTION PROJECT/STATE BORDER – BOTOVO – ZAGREB – RIJEKA

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Abstract

The planned corridor of the high performance railroad: state border (Botovo) - Zagreb - Rijeka has been given priority in Croatian Railways development plans, and it has been decided to provide double railroad track and facilitate speeds of 160 (200)km/h, throughout the route between the state border with Hungary and Rijeka. Construction of the new railroad facilitates travel between Botovo and Rijeka within slightly more than two hours. It also provides necessary conditions for achieving planned capacity of the new railroad in range of 28 to 32 million tonnes per year. The projection of the cargo traffic is based on the fact that construction of the new railroad to Rijeka and the new Rijeka port facilities significantly improve quality and competitiveness of Rijeka traffic route. Scenario III-a has been adopted as a realistic projection of cargo traffic along the new high efficiency railway Botovo – Zagreb – Rijeka. Passenger traffic projection was executed in three alternative variants, while alternative 2 is expected to fit realistic expectations the best. All of the variants and scenarios regarding traffic projections are provided in “Traffic technology and transport for Design of high efficiency railway state border – Zagreb – Rijeka design, by ŽPD (Railway Design Company), Zagreb 2008”. The route traverses exceptionally demanding landscape in its new corridor, including geologically complex areas and protected nature areas, thereby presenting a great planning and design challenge. On the basis of analyses carried out in the feasibility study it may be concluded that modernization and construction of high efficiency railroad state border – Botovo – Zagreb – Rijeka is fully justified from an economic (socio-economic) and financial (financial-market) point of view since applicable internal rates of return range from approximately 9 % in Sector north to approximately 6 % in Sector south. The new express railroad represents significant reduction of transport costs along with fulfilment of expected traffic demand, primarily due to markedly favourable operating conditions facilitated by its new route, as well as due to great reduction of travel distance between Zagreb and Rijeka.

Keywords: high performance railway line, V_b corridor, feasibility, Botovo – Rijeka

1 Corridor in general

The railway line Botovo – Zagreb – Rijeka constitutes the south section of the major Baltic-Adriatic route and a part of V_b Pan-European corridor Budapest- State Border – Zagreb – Rijeka. This route is given special importance in European traffic studies and the International Union of Railways - UIC included it in “the Instruction plan for European network development”, which comprises the most important railway lines on the continent.



Figure 1 V Pan-European Traffic Corridor

The existing single-track railway lines from Botovo to Dugo Selo and from Hrvatski Leskovac to Karlovac, which were constructed in 1865, i.e. 1870, are of valley type, and since they were designed for lower speeds they require renewal. From Karlovac to Rijeka there is a single-track railway line in the mountainous part of the route that has been in use since 1873, whose elements and throughput potential have not been able to meet the requirements of passenger and cargo transport for years. Due to major traffic and economic importance, the planned corridor of the railway line was given priority in development plans of Croatian Railways (HŽ). In the entire segment from State Border with Hungary to Rijeka, a double track line shall be introduced, capable of carrying from 28 to 32 millions of tons of freight per year, and allowing speeds of 160 (200)km/h, which will shorten the duration of journey from Botovo to Rijeka to slightly over 2 hours.

2 Traffic analysis

Due to the breakup of Yugoslavia and war circumstances, political changes in Eastern Europe and sudden development of ports in Trieste and Koper, the traffic on railway sections Botovo – Zagreb – Rijeka decreased in 1990's. After the war, the Croatian economy started to recover, and through traffic increased, which brought about the growth of traffic in the Port of Rijeka and on Rijeka railway line. Freight transport was subdivided in three parts: Port of Rijeka transport (the basis was the Master Plan of the Port of Rijeka), transport that passes through Rijeka railway junction and transport of local users in the junction. The forecast for each individual section of the railway line Botovo – Zagreb – Rijeka was developed in three basic versions and an additional scenario III-a (Table 3.), which evaluates the possibility of Bakar Port operation and realization of combined traffic on Adriatic – Danube basin line. In technological design, the scenario III-a was used as the basis for capacity determination, and in economic and financial analysis for the calculation of the internal rate of return.

Table 1 Freight transport realized (in net tons) on individual sections

No	Section	Mark	1988	2001	2006
1.	(SB) - BOTOVO - KOPRIVNICA	Bo - Ko	2.698.370	1.981.550	3.133.317
2.	KOPRIVNICA - KRIŽEVCI	Ko - Kr	4.131.132	2.632.338	3.532.983
3.	KRIŽEVCI - DUGO SELO	Kr - DS	4.177.296	2.669.066	3.539.067
4.	DUGO SELO - ZAGREB	DS - Zg	8.937.885	3.894.195	6.287.399
5.	ZAGREB - KARLOVAC	Zg - Ka	4.964.408	2.686.765	3.549.066
6.	KARLOVAC - OGULIN	Ka - Og	4.848.489	3.058.793	3.881.044
7.	OGULIN - RIJEKA	Og - Ri	4.327.701	2.222.443	2.157.205

Table 2 Passenger transport volume on Botovo – Zagreb – Rijeka railway line

No	Section	Km	Mark	2001	2006
1.	(SB) - BOTOVO - KOPRIVNICA	13,5	Bo – Ko	98.059	227.760
2.	KOPRIVNICA - KRIŽEVCI	29,8	Ko – Kr	1.132.160	1.254.064
3.	KRIŽEVCI - DUGO SELO	35,9	Kr – DS	1.891.555	2.125.530
4.	H. LESKOVAC - KARLOVAC	52,6	HL – Ka	1.071.115	1.876.048
5.	KARLOVAC - OGULIN	56,4	Ka – Og	673.196	1.000.710
6.	OGULIN - RIJEKA	119,8	Og – Ri	336.594	485.450

Table 3 Freight transport forecast for Scenario III_a (in tons)

Section	2015	2016	2020	2025	2031
Krasica-Drežnica	8.221.859	9.506.431	13.899.977	18.970.753	29.949.517
Split-Drežnica	2.499.530	2.514.052	2.572.991	2.648.611	5.067.000
Drežnica-Goljak	10.721.389	12.020.483	15.169.877	19.529.127	34.453.517
Karlovac-Goljak	388.000	396.000	390.000	490.000	660.000
Goljak-Horvati	11.109.389	12.416.483	15.559.677	20.010.175	35.113.517
D. Selo-Gradec	4.962.036	5.545.853	6.949.769	9.410.587	15.683.540
Gradec-Križevci	4.782.036	5.355.853	6.749.769	9.150.587	15.378.540
Križevci-Koprivnica	4.842.036	5.425.853	7.549.769	10.100.587	15.493.540
Koprivnica-Botovo	4.462.986	4.988.087	6.250.412	8.455.127	14.106.190

Table 4 Passenger transport forecast for version 2 (in millions of passengers)

Section	2015	2016	2020	2025	2031
Krasica-Drežnica	2,90	3,00	3,50	4,20	5,06
Split-Drežnica	2,30	2,40	2,60	2,80	3,05
Drežnica-Goljak	4,74	4,90	5,60	6,40	8,76
Goljak-Horvati	4,30	7,40	5,10	5,80	8,00
D. Selo-Gradec	3,38	3,58	4,00	4,50	5,10
Gradec-Križevci	2,48	2,67	3,07	3,54	3,95
Križevci-Koprivnica	2,68	2,89	3,37	3,38	4,40
Koprivnica-Botovo	0,51	0,54	0,60	1,20	1,86

Passenger transport forecast was made in 3 versions and Version 2, which was taken as a basis for further analysis, anticipates a growth in transport that would result from the following: the improvement in the quality of service, increase in the standard of living, completion of infrastructure facilities located in the impact zone of the new railway, impact of the rise in the price of power sources and environmental advantages of railway when compared to road traffic.

3 Elements of construction concepts of the new railway line

According to recommendations of International Union of Railways (UIC) for the European railway network, three characteristic speeds were established:

- $V = 250\text{ km/h}$ and over for new high-speed major railway lines
- $V = 200\text{ km/h} + 25\%$ for very highspeed railway lines for combined traffic
- $V = 160\text{ km/h}$ for renewed existing railway lines for combined traffic.

The new railway line is intended for combined railway transport, especially transport of great quantities of goods whose origin or destination is the Port of Rijeka. Technical parameters shall be suited to the modern high performance railway lines intended for combined traffic, which at the same time allow for passenger train traffic at speeds up to 200 km/h and freight train traffic at speeds up to 120 km/h (in the future up to 160 km/h).

Limit values of the open railway route (plan view and elevation elements):

- Design speed $V_{\max} = 160$ (200) km/h , $V_{\text{teretni}} = 100\text{ km/h}$,
- Minimum radius of curvature $R_{\min} = 3500\text{ m}$ (tunnels 6500 m),
- Maximum grade: valley route $i_{\max} = 12.5\text{ ‰}$,
- mountain route $i_{\max} = 12.5\text{ ‰}$ (tunnels 8 ‰),
- Formation level width 12.00 m ,
- Distance between tracks 5.0 m (inside the tunnel 25.0 m),
- Permitted axle load 250 kN ,
- Stopping distance 1500 m ,
- Loading of railway bridges and culverts:
Eurocode ENV-1991-3- Basis of design and actions on structures,
- Traffic loads UIC CODE 700/OR, UIC CODE 702/OR.

Limit values of the railway route inside the tunnel:

- Design speed $V_{\max} = 160\text{ km/h}$ (200 km/h),
- Minimum curvature radius $R_{\min} = 6500\text{ m}$,
- Maximum grade $i_{\max} = 8.0\text{ ‰}$,
- 3.0 m wide safe area from the danger area,
- Minimum height of the overhead line 1.10 m with the distance between fixing of max 50 m ,
- Minimum clear height of the tunnel is 6.90 m in the normal area of overhead line, and 7.30 m in the extended area of overhead line.

4 Route description and technical elements

The project of modernisation and construction of the railway line State Border– Botovo – Zagreb – Rijeka was considered in two traffic and technological units: Sector I: Dugo Selo – Botovo - SB of 78.87 km in length and Sector III: Hrvatski Leskovac – Skradnik – Krasica of 148.095 km in length, with special reference to Zagreb and Rijeka railway junction.

4.1 Concept of the railway route SB (Botovo) – Zagreb

The introduction of a second track along the existing one is planned, which will for the most part be extended within the existing railway terrain. The greatest departing from the existing

route is at the entry into Vrbovec main station, near Črnc fish pond, at the entry and exit from Križevci main station and Lepavina bypass. The design speed is 160km/h for passenger trains and 120km/h for freight trains. All curvatures with radius smaller than $R=1900m$ on the existing track shall be reconstructed before the second track is constructed. The terrain is very unfavourable on section Vojakovački Kloštar – Lepavina – Sokolovac, and the renewal of the track for higher speeds is actually a new route, with 3 tunnels.

4.2 Concept of the railway route Zagreb – Rijeka

4.2.1 Section Hrv. Leskovac – Belaj (50.325km)

The construction of a new double track railway line along the existing Zagreb – Karlovac Motorway is planned on the subsection Horvati – Goljak (23.2km). Subsection Goljak - Belaj (20.9km) is the bypass of the town of Karlovac. This is a valley part of the route, with grade up to 8mm/m and it is planned in the last phase of construction. In the previous phase, the construction of double track railway line Goljak – Karlovac Centre is planned, which is for the most part extension of the existing railway line, renewal of the existing railway line Karlovac Centre – Mostanje branching and construction of single-track connection of the existing line to the new one from Mostanje branching to Belaj.

4.2.2 Section Belaj – Skradnik (31.6km)

This is a double track railway line of valley characteristics, and Gaj interstation shall be made en-route. The railway line is in a downward grade from Skradnik to Belaj, with the largest grade of 10mm/m, except for two shorter segments which are in an upward grade of 7.5 and 8.0mm/m at distances of 1.045 and 1.280m.

4.2.3 Section Skradnik – Krasica (66.17km)

Subsection Skradnik – Drežnica (23.4km) is a double track railway line, and the route is in a constant upward grade (5.3-11.7 mm/m). There are three tunnels on the route “Veljun” - 2.770m, “Kapela 1” - 9.500m and “Drežnica” - 3.410m. The main station Drežnica on subsection Drežnica – Krasica (46.3km) is the main station at the highest elevation point of the railway line. From Drežnica main station to Krasica, the railway route is in a downward grade from 8.0 – 15.5mm/m, except in two shorter segments where it is in an upward grade of 5.1mm/m (in length of 2.393m) and 11.6mm/m (in the length of 1.733m). There is a total of 8 tunnels on the section (of total length of 22.6km, the longest tunnel is “Kapela 2”-14.040m) and 6 viaducts in total length of 11.8km (the longest viaduct is Vinodol 8.225m in length). The entire route is located in structures in the length of 33.4km (or 73%). Due to increased resistance in tunnels, the relevant resistance of the train amounts to 15 daN/t.

4.3 Investment costs of railway line construction

Investment costs include the following: cost of the railway route, main station, structures, tunnels, drainage, passage and crossings, installations, energetics, signalization and equipment, environmental protection, land, design, supervision and contingencies.

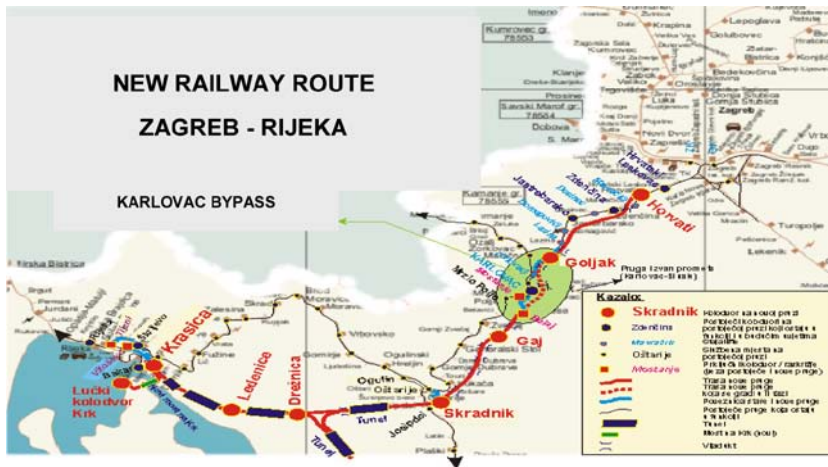


Figure 2 Planned route of the new railway line in sector III Zagreb – Rijeka

Table 5 Investment costs by sectors and sections of the railway line

INVESTMENT COSTS (€)	
SECTOR I: DUGO SELO - SB (BOTOVO) L = 78.87km	
DUGO SELO – KRIŽEVCI L = 36.93km	191.365.200,00
KRIŽEVCI – SB (BOTOVO) L = 41.94 km	278.284.476,60
TOTAL	469.649.676,60
SECTOR II: ZAGREB JUNCTION	
M102 - ZAGREB GK - DUGO SELO (v1)	221.270.740,88
M202 ZAGREB GK - SAVSKI MOST (v1)	17.564.900,42
M202 SAVSKI MOST- HRV. LESKOVAC	39.908.702,02
TOTAL	278.744.343,32
SECTOR III: HRV. LESKOVAC – KRASICA L = 148.095km	
HRV. LESKOVAC – BELAJ L = 50.325km	587.024.320,80
BELAJ – SKRADNIK L = 31.6km	432.995.611,81
SKRADNIK – KRASICA L = 66.17km	1.444.577.693,43
TOTAL	2.464.597.626,04
SECTOR IV: RIJEKA JUNCTION	
M202 ŠKRLJEVO – RIJEKA	80.460.818,51
M202 RIJEKA – JURDANI	137.615.376,23
NEW RAILWAY LINE KRASICA - TIJANI – IVANI	165.501.578,97
NEW BYPASS FOR FREIGHT TRANSPORT KRASICA - TIJANI – MATULJI	400.116.600,00
NEW BYPASS FOR FREIGHT TRANSPORT - UČKA TUNNEL – BORUT	225.003.378,60
TOTAL	1.008.697.752,31
OVERALL	4.221.689.398,27

5 Economic and financial analyses of the railway line construction project SB – Botovo – Zagreb – Rijeka

The procedure of evaluation of the new railway line construction project SB – Botovo – Zagreb – Rijeka was defined in accordance with *Council Directive 91/440/EEC on the Development of Community's Railways (31991L0440)*. The basis for economic and financial assessment of the railway line represents cost and benefit flow in a 30-year period which includes: operating costs, overhead costs, passenger's time cost, costs of construction and maintenance. Operating costs were established for the case of existing SB – Zagreb-Rijeka and new railway line Zagreb – Rijeka and the extension of Zagreb – Botovo – SB railway line.

Evaluation was conducted by determining the internal rate of return (IRR), carried out for both cases, "with" and "without" the construction of the new railway line. Pure benefits were determined for the first year of operation (linear trend) of traffic growth in a 30-year period. Evaluation of the new railway line was carried out from the aspect of the community (social and economic) and from the aspect of HŽ (financial and market).

Figure 3 shows the results of internal rate of return calculation for economic and financial assessment. Phase I of Sector South represents the construction of section Skradnik – Krastica, and phase II represents the construction of sections Hr. Leskovac – Belaj – Skradnik.

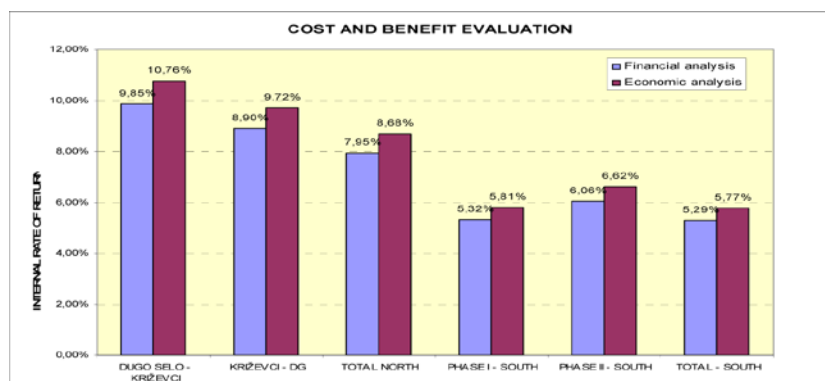


Figure 3 Cost and benefit evaluation by sectors and sections of the railway line

6 Conclusion

The concerned railway line Botovo – Zagreb – Rijeka is a major railway route for connecting central Croatia, Gorski Kotar and Northern Croatian Littoral, and owing to the markedly favourable position of the Port of Rijeka, at the same time it represents the shortest and the most economic route for connecting Central and North Europe to the Mediterranean and further on, with the countries of the Middle and Far East through Suez Canal. Modernisation of this railway line shall have multifold significance for the economic development of our country. Based on the analyses that were carried out within the feasibility study it can be concluded that modernisation and construction of the high performance railway line SB-Botovo-Zagreb-Rijeka, including the satisfaction of the overall expected transport demand, involves a significant decrease in transportation costs, primarily due to excellent operating conditions of the new route and secondly due to great shortening of travel distance between Zagreb and Rijeka. The project is completely justified from economic (social and economic) and financial (financial and marketing) aspect, since the internal rates of return are at the level of around 9 % in Sector North, and around 6% in Sector South.

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