RECONSTRUCTION AND MODERNIZATION OF RAILWAY LINE STALAĆ – KRALJEVO – RUDNICA – OPTION ANALYSIS

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Abstract

Serbia is upgrading its Core Railway Network in line with international agreements with a view to reaching the EU standards of interoperability. It aims to revitalise and develop the railway network giving priority to Pan-European Corridor X, which is the backbone of the system, and to SEETO routes 10 and 11 (as part of Indicative Extension of TEN-T Core rail network) on which the Stalać-Kraljevo-Rudnica line is located. The overall objective of Reconstruction and modernization of the railway line Stalać-Kraljevo-Rudnica is to safeguard the functionality by aligning it with the relevant standards as specified in the TEN-T regulations and TSI requirements. The purpose of this paper is to define the options for each of the proposed parameters (Single-track or Double-track, Axle load, Design speed, Technical solutions for structures (tunnels, bridges, underpasses and overpasses), Electrification, Signalling, Telecommunications and management, Stations, Environmental protection and Social Environment) and select the desired option.

Keywords: railway line, reconstruction, modernization, option analysis, parameters

1 Introduction

Modernization, reconstruction and construction of the railway network in Serbia aims to create a modern and functional trasport network that will in part be integrated in the united Trans European network. In line with international agreements, and with the goal of reaching the standards of interoperability with the EU, Serbia is upgrading its railways, giving priority to the railways on the Pan-European Corridor X, and also routes 4, 7, 10, 11, 9A and 13 (SEETO network) [2]. The general goal of the upgrades to the national railway network is an improvement in the functionality of the high priority railway sections, with compliance with TEN-T and TSI requrements [1, 6].
As one of the priorities of the development of railway infrastructure in Serbia, the project of reconstruction and modernisation has already begun on the Stalać-Kraljevo railway on route 11 and the Kraljevo – Rudnica railway on route 10, based on European initiatives and strategies. The strategic goal of reconstructing and modernising the railroad section Stalać-Kraljevo-Rudnica is creating larger transport capacities for transport towards the port of Bar, Macedonia and Greece.

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Figure 1 Expansion of the TEN-T railways into the western Balkan with the placement of the Stalać-Kraljevo-Rudnica railway.

The improvements to the railway infrastructure in the already mentioned sections will contribute to the establishment of high quality regional passenger traffic, by which a good connection will be made between south Serbia and Belgrade, while when it comes to cargo transport, the needs of local economy will be meet, primarily the automobile industry and energetics. The task of the Previous feasibility study and the General reconstruction and modernisation project of the railway section Stalać-Kraljevo-Rudnica (WBIF WB14-SRB-TRA-01) was to define alternative solutions and ways in which the reconstruction and modernisation of railroad sections could be carried out in line with the requirements of modern transport systems, then comparing them on a functional, technical, economical, financial, spatial, ecological and social level, and making the decision on the optimal variant solution.

1.1 Analysis of the state of the existing railway sections

By using the data collected from the infrastructure management, and the data collected during railway inspection, a thorough analysis has been performed of the topographical, geological, spatial and ecological conditions, and the general state of railway infrastructure.
Both of the railway sections, Stalać - Kraljevo and Kraljevo – Rudnica are single-track and not electrified. The lenght of the section from Stalać to Kraljevo is ~72 km, while the length of the section from Kraljevo to Rudnica is ~77 km.
According to the allowed mass of vehicles, the Stalać-Kraljevo section belongs to the B2 (180 kN, 64 kN/m) category, while the Kraljevo-Rudnica section belongs to the C3 (200 kN, 72 kN/m) category.
On the Stalać – Kraljevo section, trains achieve the top speed of 40 km/h, while trains on the Kraljevo – Rudnica section achieve the top speed of 60 km/h. There are 20 stations on the railway sections (9 on the section Stalać-Kraljevo and 11 on the section Kraljevo-Rudnica).In order to rationalize its workforce and business, Joint Stock Company Serbian Railways closed some of stations and converted them into hault stations. At the moment, there are 4 stations on the section Stalac-Kraljevo and 8 stations on the section Kraljevo-Rudnica. The buildings, equipment and devices in the stations are in poor condition.The equipment is outdated and insufficient. Passenger service areas (halls, ticketing, waiting rooms and platforms) are not equipped with modern passenger information devices and ticketing service system. Administrative offices and facilities meant for railway service users are not equipped with modern equipment. Many of station buildings require different levels of intervention.

Figure 2 Official posts on the Stalać-Kraljevo-Rudnica railway

Railway signalisation and security systems mostly consist of electromechanical devices with light signals and above-ground telecommunication lines. The equipment is obsolete and insufficient. The signalisation equipment on the railway is either does not exist or does not work. The telecommunication systems are based on analogue telephony. The telecommunication platform does not support IT. The stations are not equipped with modern technology systems.
The Stalać – Kraljevo section has two (2) pairs of passenger trains, while the Kraljevo – Rudnica section has three (3) pairs of passenger trains (that go to Kosovska Mitrovica).

2 Methodology applied for the analysis and selecting options

The suggested methodology can be summed up in two phases:
- Defining of the variable solutions, based on an independent evaluation of the adopted parameters.
- Cost – benefit analysis.

The analysis of the current state of the railways, in terms of traffic indicators, infrastructure, functioning/operation, etc. provided the basis for:
- Identification of the functionality of the railway, both the existing and the planned one.
- Identification of the need for railway modernisation and reconstruction.

Accepting the recommendations of the Joint Assistence to Support Projects in European Regions (JASPERS) for defining of the variable solution options, a simplified methodology was applied, evaluating each of the parameters individually, while rejecting those parameters that have no influence on the decision on a variable solution. The process can be seen as a series of filters where:
- Every filter removes some of the variants.
- As the number of variants that need testing decreases, the level of work on each individual filter increases.
- Variants that do not show a clear advantage during testing or quick evaluation, can be discarded early.
- Hipothetically, in the case where different variants cannot be simply eliminated after a quick evaluation, each should be thoroughly evaluated.
- Sustainable variants, with more potential, that are included in the package for detailed evaluation are the ones that pass through all the filters.

The evaluation process focuses on determining whether a solution and/or its variation is strategically in line with the goals of the transport system, including the goals of the end user, strategies, plans and procedures.

2.1 Definition of variable solutions, based on an independent assessment of the adopted parameters

The key parameters used in the process of defining the alternative solutions were:
- number of tracks (single-track or double-track railway),
- axle load,
- design speed,
- solutions for infrastructural objects (tunnels and bridges),
- electrification (whether it is necessary to project electrification or not),
- safety signalling and telecommunication facilities and devices,
- stations,
- environmental protection and social environment.

The need for a single-track or double-track railway is based on an assessment of the current need for traffic, future demand for transport services, as well as throughput. In order to fully meet the transport requirement in the period of 30 years from the completion of modernization and reconstruction of railway sections (period from 2027 to 2057), it is necessary to provide:
- seventeen (17) trains in both directions according to pessimistic forecasts or twenty-nine (29) trains in both directions according to optimistic forecasts, on the section from Stalać to Kraljevo,
- twenty-seven (27) trains in both directions according to pessimistic forecasts or forty-two (42) trains in both directions according to optimistic forecasts, on the section from Kraljevo to Rudnica.

Based on the forecast and calculation of capacity on the section from Stalać to Kraljevo, it is shown that the current situation in terms of the number of official positions in operation (with increasing speed) can meet all transport requirements in the planned period.
Since the routes 10 and 11 are located on the comprehensive TEN-T network, the axle load on the railway sections is defined in accordance with Regulation 1315/2016, Article 39, which prescribes/provides for-stipulates the axle load of 22.5 t as a minimum [1].
Depending on the geometric elements of the route, the permissible speeds at the inter-station/stop distances have been defined. Depending on the designed geometric elements of the route which have a minimal impact on expropriation, while at the same time meeting the requirements of TSI and TEN-T [4] regulations, variant solutions have been defined in relation to the allowed speeds. An overview of variant solutions defined as a function of designed speed is shown in Table 1.

Table 1 Overview of variant solutions defined in terms of design speed

Variant solution	Design speed
S 1.1	Stalać-Kraljevo: Speed V = min 60 km/h (min R300) – Retaining the existing speed limit with a correction of horizontal curve radius to min 300m.
S 1.2	Stalać-Kraljevo: Speed V= min 80 km/h – Increasing the speed to min 80km/h with the correction of geometric railway elements where necessary.
S 1.3	Stalać-Kraljevo: Speed V = min100 km/h – Increasing the speed to min100 km/h with the correction of geometric elements of the railway where necessary.
S 1.4	Stalać-Kraljevo: Speed V = min120 km/h – Increasing the speed to min120 km/h with the correction of geometric elements of the railway where necessary.
S 2.1	Kraljevo-Rudnica: Speed min 60 km/h (min R300) - Retaining the existing speed limit with a correction of horizontal curve radius to min 300m.
S 2.2	Kraljevo-Rudnica: Speed V = min 80 km/h - Increasing the speed to min 80 km/h with the correction of geometric elements of the railway where necessary.
S 2.3	Kraljevo-Rudnica: S 2.3 Speed V = min 100 km/h – Increasing the speed to min100 km/h with the correction of geometric elements of the railway where necessary.

According to the required national and international regulations, the reconstruction of the tunnel should include an increase in the area of the clear profile so that the railway should allow unhindered passage of the railway vehicles that, together with the cargo they carry, have a GC loading gauge. Based on the verification of the bearing capacity of the existing bridges, a decision is made on the scope of intervention for each individual facility. Where the load-bearing requirement is not satisfied, it is necessary to reinforce the structures. If the control shows that reinforcement is not possible and that the bearing capacity is significantly endangered, it is necessary to design a new facility. Electrification of the railway sections is envisaged on the basis of strategic decisions and development plans of the Serbian Railway Infrastructure, as well as on the basis of the Spatial Plan of the Republic of Serbia [4].
The section of the railway from Požega to Kraljevo, including the station in Kraljevo, is electrified, as is the railway on Corridor X, which passes through Stalać.
Considering the fact that along the line/railroad between Požega and Stalać only the section from Stalać to Kraljevo is not electrified, the conclusion is that it is necessary to envisage electrification of this section as well in order to avoid expenses/costs and reduce/shorten the travel time of trains due to the replacement of the electric locomotives/engines with diesel locomotives.
The reason for designing the electrification of the Kraljevo - Rudnica section is the planned expansion of Route 10, from Jarinje to the border crossing with Northern Macedonia, in order to ensure interoperability and thereby allow a smooth flow of traffic.
The improvement of safety-signalling and telecommunication plants and devices is mainly based on the application of modern technological solutions that satisfy both national and ER regulations.
The technical solution for both sections should encompass a complete upgrade, based on the principles of ETCS1 and the local railway network based on IT with optic infrastructure.
The number of tracks in the stations on the sections of Stalać - Kraljevo and Kraljevo - Rudnica is sufficient for the planned scope of operation/work. The tracks in the stations are to be reconstructed in accordance with the TSI requirements as regards/in terms of useful lengths.
From the point of view of environmental protection, variant solutions that do not depart significantly from the existing conditions are considered to be more favourable. Since these are inhabited and protected areas, lager departures from the existing railway will cause extensive expropriation and demolition of facilities, and also have a greater impact on archaeological sites and ecologically significant areas.

2.2 Cost – Benefit Analysis

The Cost-Benefit Analysis (Table 2) considered options defined as a combination of alternative solutions. Estimated costs of reconstruction for Option 1 amount to a total of EUR 473.431.173, Option 2 - 473.490.973, and Option 3 - 490.310.179. The prices do not include VAT and unforeseen works. Investment costs are based on the project and unit prices in the region.

Table 2 Options obtained by combining variant solutions for the need of producing Cost-Benefit analysis

Section	Stalać-Kraljevo			Kraljevo-Rudnica
Solution variant/version	S1.2/S1.3	S1.2/S1.4	S1.3	S2.2
Option 1	■			■
Option 2		■		■
Option 3			■	■

The reconstruction and modernization of the Stalać-Kraljevo-Rudnica railway is expected to be completed within a period of seven years, and the beginning is due in the first quarter of 2027.The project was analysed for the time period of 30 years, including the construction period, i.e. from 2027 to 2056. Future transport forecast requirements are based on:

- Identification of previous traffic flows on all railway and road sections included in the Referent Traffic Network. Existing traffic flows are identified for the base year of 2016.
- Development of growth factors that will be applied to existing traffic flows.
- Estimations of diverted traffic flows from road to railway after the modernization of the railway line.
- New traffic requirement – maximum capacity utilization of mines located along the related railway corridor.

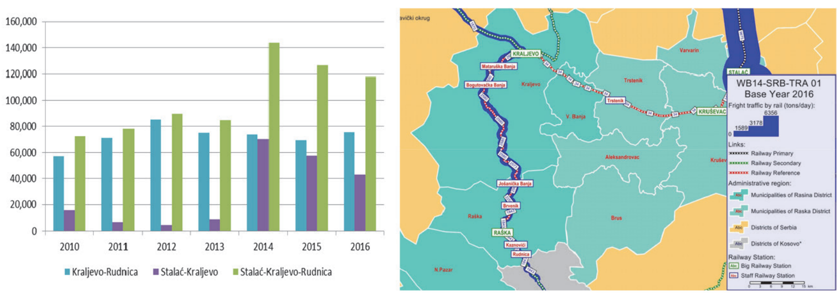

Figure 3 Annual number of passengers on the railway line in question (2010-2016) and freight on the line in 2016 (tons / day)

The CBA was conducted based on the instructions provided in the Guide to Cost-Benefit Analysis of Investment Projects. [8]

The financial return of investment costs is estimated by the indicators: financial net present value of investment FNPV (C) and financial internal rate of return FIRR (C). Table 3 shows financial analysis indicators for a discount rate of 4 %.

Table 3 Financial analysis indicators for a discount rate of 4 %

	Option 1 and 2	Option 3
FNPV (EUR)	-262.567.755 < 0	-243.954.173 < 0
FIRR (%)	-7.32 < 4	-5.89 < 4

Financial analysis indicators for a discount rate of 8 % are also negative. The financial analysis indicates that the investment defined in this way cannot be self-financed, and the revenues themselves would not be sufficient for mandatory loan repayment, so it would be necessary to provide a grant for the implementation of this investment or subvention for loan repayment by the State.

The economic analysis was done based on constant prices and adopted values of the discount rate of 5 % [8].The following elements were considered within the economic analysis: investment costs, maintenance costs, travel time savings, delay costs, accident savings, air pollution savings, noise savings, climate change / global warming savings, marginal infrastructure costs, vehicle operating costs (VOC), train operating costs (TOC) and secondary materials. Economic analysis indicators are shown in Table 4.

Table 4 Results of economic assessment

	Discount rate 5%	
	Option 1 and 2	**Option 3**
ENPV (EUR)	97.996.342 > 0	103.478.510 > 0
EIRR (%)	9.65 > 0	9.46 > 0
B/C	1.52 > 1	1.58 > 1

Economic analysis shows that the project is justified for society, ie. as a social investment, and is recommended for the further implementation.

3 Conclusion

For the railway Stalać-Kraljevo-Rudnica, possible alternative solutions for the railway have been designed, along with options for the reconstruction and modernization in keeping with the requirements for modern transportation systems and their mutual comparison was performed in terms of functional, technical, economic and financial aspects.

To define variant solutions, a simplified methodology was applied, which involved evaluating each of the parameters individually, rejecting the parameters that had no influence on the decision on the variant solution.

The combination of variant solutions was used to define the options that were considered within the Cost-Benefit analysis.

The presented results for options 1 and 2 and for option 3 are very close in terms of economic performance indicators and therefore a more detailed investment cost analysis and cost-benefit analysis should be performed in the preliminary design phase.

All the indicators that are analyzed speak about the fact that this project is sustainable and acceptable from the socio-economic point of view, but also about the fact that there is a need and justification for co-financing through EU funds or other sources. Specific details about the source of financing/funding will need to be determined at the level of preparation/producing a feasibility study with the preliminary design.

References

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