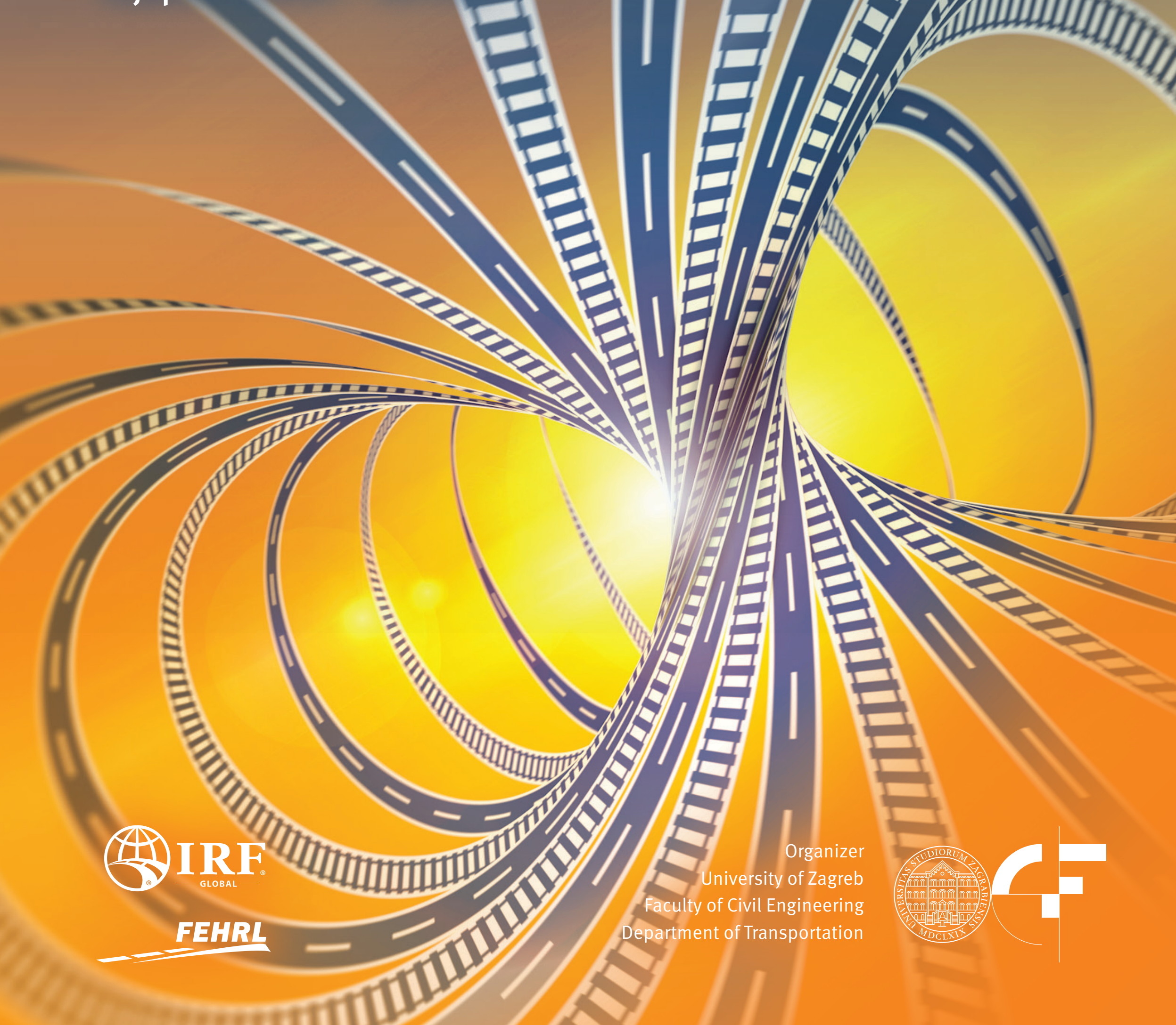
CETRA 2018

5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR



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CETRA[2018]
5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

TITLE
Road and Rail Infrastructure V, Proceedings of the Conference CETRA 2018

EDITED BY
Stjepan Lakušić

ISSN
1848-9850

ISBN
978-953-8168-25-3

DOI
10.5592/CO/CETRA.2018

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.
Marko Uremović · Matej Korlaet

PRINTED IN ZAGREB, CROATIA BY
“Tiskara Zelina”, May 2018

COPIES
500

Zagreb, May 2018.

Proceedings of the
5th International Conference on Road and Rail Infrastructures – CETRA 2018
17–19 May 2018, Zadar, Croatia

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CETRA[2018] 17–19 May 2018, Zadar, Croatia
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PRIORITIZATION OF RAILWAY INFRASTRUCTURE PROJECTS USING THE ANP APPROACH – CASE STUDY SERBIAN RAILWAY NETWORK

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Abstract

One of the strategic goals of each country is the transport infrastructure development. The realization of transport infrastructure projects provides faster economic and social development of the country and the region as well. Considering the railway sector, at the beginning, it is necessary to prepare project's documentation that depends on the selected level of the railway infrastructure development. The types of the railway infrastructure improvement in the Republic of Serbia are defined as follows: renewal or rehabilitation, reconstruction, modernization and construction of railway lines. The time of completion of the works related to certain type of improvement varies according to scope and type of works, the terrains on which railway line is located, the liquidity of the country, as well as the willingness of international financial institutions to provide loans. Considering the limited availability of loan resources and the inability of the country to provide greater guarantees, further prioritization of railway infrastructure projects is necessary. In the process of prioritization it's essential to consider economic and financial indicators, that define the feasibility of the project, but also other relevant technological indicators. In this paper, the proposed method for ranking railway infrastructure projects is the multi-criteria approach – Analytic Network Process, ANP. The developed model is tested on the data related to the railway infrastructure projects in the Republic of Serbia.

Keywords: Railway projects, Projects prioritization, Analytic Network Process

1 Introduction

Due to its life cycle, railway infrastructure can be exploited for a long time without investing in its maintenance. However, if an infrastructure manager wants to ensure infrastructure's reliability and safety, and be economical, it is better to invest in the maintenance today.

Non-providing funds for a long time for regular maintenance of the railway infrastructure in the Republic of Serbia, and no replacement of fixed assets have caused a low level of technical reliability, thus leading to imposing of a large number of speed limits in order to maintain the safety of railway transport, which consequently interrupted the realization of the planned train schedule. For these reasons the Republic of Serbia has made great efforts in providing funds from international financial institutions in the past few years.

So far, some projects have been completed or launched on Corridor X, while in the future, several large projects with provided funds are expected to start. These projects have been identified in the relevant strategies for the development of railway infrastructure, as well as in the National Program for Public Railway Infrastructure for the period 2017-2021 [1].

The backbone of the railway network in Serbia is part of the Pan-European traffic Corridor X Salzburg-Ljubljana-Zagreb-Šid-Belgrade-Niš-Preševo-Skopje-Veles-Thessaloniki. In Serbia,

DOI: https://doi.org/10.5592/CO/CETRA.2018.755

Corridor X has two more parts: Corridor Xc, from Belgrade through Subotica to Budapest; and Corridor Xb, from Niš through Dimitrovgrad and Sofia to Istanbul.
In order to emphasize the significance of Corridor X from the aspect of the European transport system, it should be noted that this corridor represents an indicative extension to the Trans-European Transport Networks on the territory of Western Balkans, which is included in Annex 1 of Regulation 1315/2010 on Union guidelines for the development of the Trans-European Transport Network [2].
The subject of this paper is the prioritization of projects for which funds are not provided and where time of implementation is uncertain. The applied methodology for this problem is the Multi-criteria decision making method – Analytic Network Process, ANP. Our case study will include projects on the mentioned Corridor X and above mentioned railway routes. Their prioritization will be based on selected relevant criteria, in order to provide comprehensive information for making justified investment decisions.

2 Applied methodology

Analytic Network Process (Thomas Saaty, 1996) is the multi-criteria approach, which is suitable for problems with network structure [3]. Using the Saaty 1-9 scale the pairwise comparison matrices should be developed. These matrices present the priority among elements. Elements are grouped into clusters, and clusters make a network. After all interactions between system elements are defined, and pairwise comparison matrices are developed, the user-friendly software "SuperDecisions" (www.superdecisions.com) is used to calculate the final alternatives' rank.
There are various multi-criteria approaches, but ANP approach has some specific advantages, such as: network structure of system elements, it allows loops and feedback connections in a model, there is the commercial software, etc. On the other hand, there are some weaknesses in this approach. For instance, it becomes very difficult to apply ANP approach when there are a lot of elements in a system.

3 Case study

In the previous period, a large number of railway infrastructure projects have been completed and launched in order to strengthen the market position and increase the competitiveness of railway transport. In addition to this, further aim is the standardization of the railway transport system of the Republic of Serbia according to the European Union system. Considering the limited availability of loan resources and the inability of Serbia to provide greater guarantees in the budget, further prioritization of railway infrastructure projects is necessary. These railway infrastructure projects (Table 1) have been identified in the National Program [1]. Also, this program has defined the types of improvement of the railway infrastructure. These types of improvement are: renewal, reconstruction, modernization and construction of railways. The considered alternatives, i.e. relevant railway infrastructure projects, are presented at Figure 1. The projects related to the modernization and construction, and the reconstruction will be considered in this paper. In regard to modernization, the goal is to fulfil EU capacity requirements and quality standards relevant to the TEN-T network (in terms of track length and layouts, signalling and telecommunication systems), and enhance and reinforce Serbian capacities in the context of the EU pre-accession process. The general aim is an improvement of quality standards in order to make Serbian railway network more competitive at the transport market, but mainly in competition with Corridor IV. Here are included projects on Corridor X:

1) The project of reconstruction of the double-track railway line Velika Plana-Niš (A2, A3, A4 and A5),
2) Golubinci – Šid – Croatia border (A6).

Table 1 Considered alternatives

	Alternative	Length	No. of tracks
A1	Niš – Preševo – Macedonia border	92	1
A2	Velika Plana – Gilje	49	2
A3	Paraćin – Stalać	22	2
A4	Stalać – Đunis	17	1
A5	Đunis – Niš	40	2
A6	Golubinci – Šid – Croatia border	81	1
A7	Pančevo – Vršac – Romania border	75	1
A8	Stalać – Kraljevo – Rudnica	149	1
A9	Valjevo – Vrbnica – Montenegro border	209.4	1

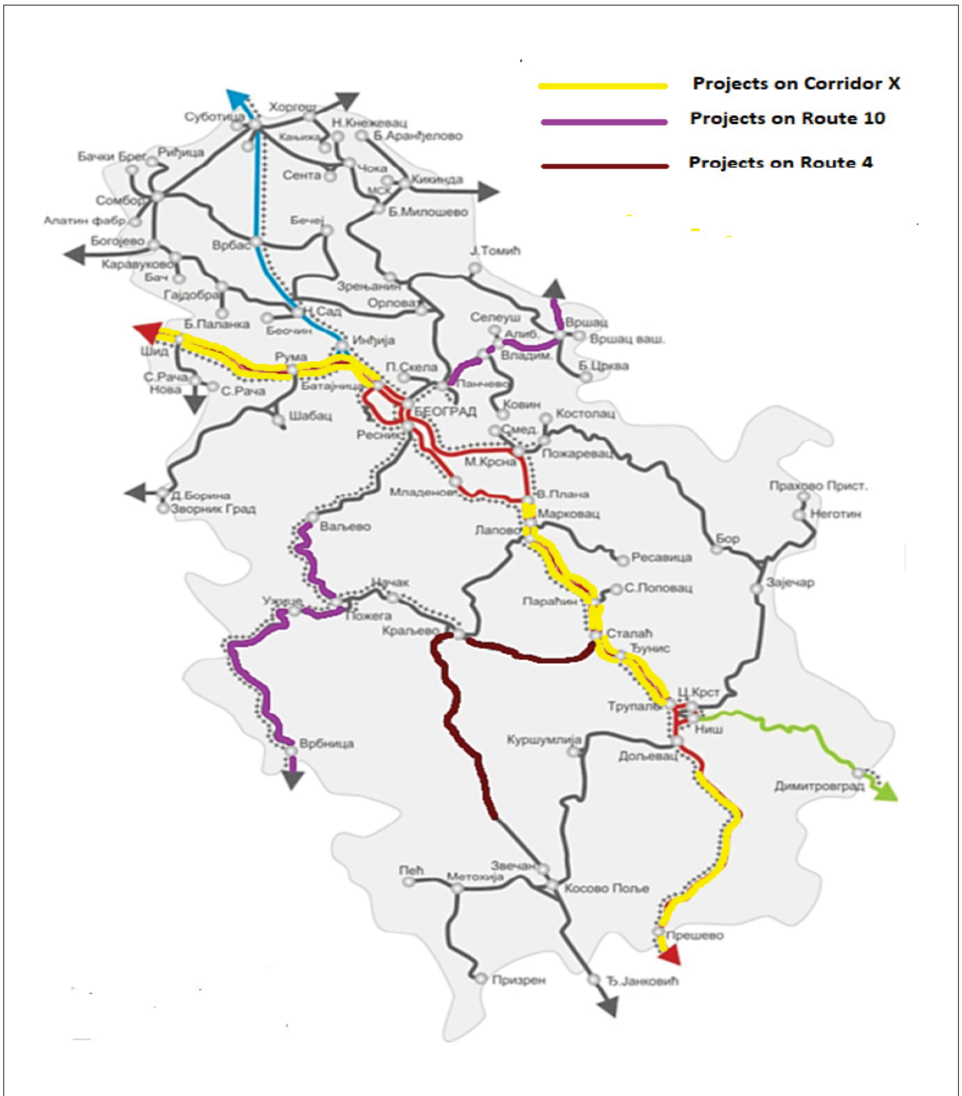

Figure 1 Considered railway sections

According to the National Program, the scope of works on these sections includes the modernization and reconstruction of both railway tracks and all station tracks for train speeds up to 160 km/h with axle load 225 kN, and the installation of electronic signals and safety and telecommunication facilities, enabling deployment of ETCS and GSM-R, i.e. ERTMS. The only exception is the section Stalać-Đunis, where the construction of new double-track railway line for speed up to 160 km/h is planned.

In regard to reconstruction, the goal is to reach the level of the railway infrastructure that is comparable and compatible with the level in the member states of the European Union in order to unify the characteristics of transport infrastructure and flows.
Here are included the following projects on Corridor X, Route 10 and Route 4: A1, A7, A8 and A9. The scope of works on these sections includes the reconstruction of railway line for train speeds of up to 120 km/h and axle loads to 225 kN, equipment of tracks, stations and level crossings with electronic signalling devices, the equipment of entire length railway with stable electric towing facilities and line optical cables for the digitization of railway communication. Considered criteria are presented in the following table. The criteria were selected in order to take in all possible factors that may influence the process of making relevant decisions for investment in railway infrastructure.

Table 2 Selected criteria

	Criteria	Description
C1	Cost	Million EUR/km
C2	Interoperability	Yes/No
C3	Technical documentation stage completion	Initial, Intermediate, Final
stage		
C4	Traffic volume	[train/day]
C5	Railway infrastructure capacity utilization	[%]

Cost

Values of the projects are taken from the National Program [1]. These values are divided by length of single track railway line.

Interoperability of railway lines

In order to be considered as interoperable, a railway line needs to fulfil a large number of defined parameters. The parameters which have been identified in Regulation 1315/2013 were considered in the paper. According to this Regulation, the following requirements should be met by the railway infrastructure of the core network [2]:

1) full electrification of the line tracks and sidings, as far as necessary for electric train operations;
2) freight lines of the core network as indicated in Annex I: at least 225 kN axle load, 100 km/h line speed and the possibility of running trains with a length of 740 m;
3) full deployment of ERTMS;
4) nominal track gauge for new railway lines: 1 435 mm (except in some cases).

Technical documentation stage completion

Having in mind previous situations when the funds were provided for project with incomplete documentation which led to the project postponed, we believe that the most important criterion for decision-making should be the Technical documentation stage completion.
Initial stage of technical documentation completion means that projects are without documentation or with only a General Design. Intermediate stage of technical documentation completion implies that projects have a Preliminary Design in preparation, and the Final stage of technical documentation completion means that projects have completed a Preliminary Design and prepared a Design for building permit.

Traffic volume per day

Traffic volume represents trains intensity on railway line in 24 hour period. The measure of these criteria is number of trains per day.

Capacity utilization

Capacity can be defined as the total number of trains that may operate on a railway section during a certain time period. The values of this criterion, as well as the values of criterion Traffic volume per day, are taken from Master plan for railways for 2012-2021 for Republic of Serbia [4]. The data for project Stalać-Kraljevo-Rudnica were received from the consultants working on the preparation of the General Design with Pre-Feasibility Study. In Master plan for railways, consultants used methods UIC Code 406 and UIC Code 405R.

Our model has the network structure, with three clusters: Goal, Criteria and Alternatives. The goals of the model are the efficiency of project implementation and achievement of the biggest effect with implemented project. The goal of the model is the efficiency of project implementation, that will improve railway infrastructure performance and make the railway transport the backbone of an efficient and sustainable multimodal transport system. The cluster “Criteria” has 5 nodes, and the cluster “Alternatives” has 9 nodes. There is an assumption that interoperability influences the time necessary for documents preparation and project’s costs. Due to this fact, the cluster “Criteria” has the loop.

4 Results and discussion

The final results are presented in Table 3 and Table 4. The criterion “Technical documentation stage completion” has the biggest weight. The reason for this is that without the completed technical documentation, the project cannot start, or in worst scenario, which has been already seen in the Republic of Serbia, to sign a financial contract for project without the completed technical documentation, and to pay penalties due to the delayed start of project realization.

Table 3 Criteria pairwise matrix with criteria weights and final rank

Criteria	C1	C2	C3	C4	C5	W_i	Rank
C1	1	1/5	1/7	1/3	1/3	0.125	4
C2		1	1/3	2	2	0.198	2
C3			1	3	5	0.440	1
C4				1	3	0.150	3
C5					1	0.086	5

Table 4 Alternative’s weights and final rank

	Alternative	Weight	Rank
A1	Niš – Preševo – Macedonia border	0.054	8
A2	Velika Plana – Gilje	0.153	2
A3	Paraćin – Stalać	0.138	3
A4	Stalać – Đunis	0.283	1
A5	Đunis – Niš	0.112	4
A6	Golubinci – Šid – Croatia border	0.062	7
A7	Pančevo – Vršac – Romania border	0.078	5
A8	Stalać – Kraljevo – Rudnica	0.048	9
A9	Valjevo – Vrbnica – Montenegro border	0.073	6

Table 4 shows the final alternatives rank. The first ranked projects are the sections of major railway line Belgrade-Niš (A2-A5). This railway line represents the line with the most intensive traffic and the aim of the reconstruction and modification is to achieve competitiveness with road traffic. The other projects (A1, A6-A9) are on lower positions on this rank list, because they require higher investment costs and they are without technical documentation.

5 Conclusion

The prioritization of railway infrastructure projects is the topic of this paper. The developed model is based on the ANP approach, with the aim of considering the network structure of the system's elements. The model is tested on real railway infrastructure projects related to the Serbian railway network.
The developed model has the network structure made of three clusters: goal, criteria (with 5 nodes) and alternatives (with 9 nodes). The first ranked criterion is "Technical documentation stage completion", and the first alternative is Stalać-Đunis. The obtained results are in accordance with local railway experts' opinion.
Future research will be dedicated to the fuzzy logic integration, in order to describe the criterion "Technical documentation stage completion" by linguistic phrases. This criterion is characterized by a great uncertainty, which should be considered as well.

Acknowledgement

This work was partially supported by Ministry of Education, Science and Technological Development, Republic of Serbia, through the project TR36022.

References

[1] National Program for Public Railway Infrastructure for the period 2017-2021, The Republic of Serbia. Available at: http://www.parlament.gov.rs/upload/archive/files/lat/pdf/akta_procedura/2017/859-17 %20lat.pdf

[2] https://eur-lex.europa.eu

[3] Saaty, T.: Decision Making with Dependence and Feedback: The Analytic Network Process, ISBN 0-9620317-9-8, RWS, 1996.

[4] Technical assistance to railway infrastructure (Master plan for railways for 2012-2021), EIB, WBIF, Ministry of Transport of Republic of Serbia and Italferr S.p.A, 2015.