CETRA 2014

3rd International Conference on Road and Rail Infrastructure
28–30 April 2014, Split, Croatia

Road and Rail Infrastructure III

Stjepan Lakušić – EDITOR

Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA 2014
3rd International Conference on Road and Rail Infrastructure
28–30 April 2014, Split, Croatia

TITLE
Road and Rail Infrastructure III, Proceedings of the Conference CETRA 2014

EDITED BY
Stjepan Lakušić

ISSN
1848-9850

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", April 2014

COPIES
400

Zagreb, April 2014.

Proceedings of the
3rd International Conference on Road and Rail Infrastructures – CETRA 2014
28–30 April 2014, Split, Croatia

Road and Rail Infrastructure III

EDITOR
Stjepan Lakušić
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Zagreb, Croatia

ORGANISATION

CHAIRMEN

Prof. Stjepan Lakušić, University of Zagreb, Faculty of Civil Engineering
Prof. Željko Korlaet, University of Zagreb, Faculty of Civil Engineering

ORGANIZING COMMITTEE

Prof. Stjepan Lakušić
Prof. Željko Korlaet
Prof. Vesna Dragčević
Prof. Tatjana Rukavina
Assist. Prof. Ivica Stančerić
dr. Maja Ahac
Ivo Haladin
dr. Saša Ahac
Josipa Domitrović
Tamara Džambas

All members of CETRA 2014 Conference Organizing Committee are professors and assistants of the Department of Transportation, Faculty of Civil Engineering at University of Zagreb.

INTERNATIONAL ACADEMIC SCIENTIFIC COMMITTEE

Prof. Vesna Dragčević, University of Zagreb
Prof. Isfendiyar Egeli, Izmir Institute of Technology
Prof. Rudolf Eger, RheinMain University
Prof. Ešref Gačanin, Univeristy of Sarajevo
Prof. Nenad Gucunski, Rutgers University
Prof. Libor Izvolt, University of Zilina
Prof. Lajos Kisgyörgy, Budapest University of Technology and Economics
Prof. Željko Korlaet, University of Zagreb
Prof. Zoran Krakutovski, University of Skopje
Prof. Stjepan Lakušić, University of Zagreb
Prof. Dirk Lauwers, Ghent University
Prof. Zili Li, Delft University of Technology
Prof. Janusz Madejski, Silesian University of Technology
Prof. Goran Mladenović, University of Belgrade
Prof. Otto Plašek, Brno University of Technology
Prof. Vassilios A. Profillidis, Democritus University of Thrace
Prof. Carmen Racanel, Technical University of Civil Engineering Bucharest
Prof. Tatjana Rukavina, University of Zagreb
Prof. Andreas Schoebel, Vienna University of Technology
Prof. Mirjana Tomičić-Torlaković, University of Belgrade
Prof. Audrius Vaitkus, Vilnius Gediminas Technical University
Prof. Nencho Nenov, University of Transport in Sofia
Prof. Marijan Žura, University of Ljubljana

THE STRATEGY OF INTRODUCING ECTS SAFETY SYSTEM ON RAILWAY CORRIDOR Vc IN BOSNIA AND HERZEGOVINA

Igor Marković
Railways of the Federation of Bosnia and Herzegovina, Sarajevo, Bosnia and Herzegovina

Abstract

ETCS (European Train Control System) is a unique European standard for controlling and managing a railway traffic. It was a result in a form of need for mutual railway abovestandard in European countries which has a goal to adjust the existing systems of railway managing and to create a unique European system of insurance which has a result to creat a unique European railway network. Beside the mentioned reasons for introducing the ETCS system other reasons are the increasing diversion of cargo flows from road to rail. To implement the ETCS system on BH railways at Corridor Vc it is necessary to analyse present state of railway infrastructure and to adjust and renew infrastructure so it would be prepared for installation of ETCS system. In this paper a possibility of introducing of this security on BH railway at Corridor Vc was presented. Implanting of ETCS security system was presented throughout four project options. Project options allude implementation of ETCS separatly for each level of that system. First project option refers to implementation and modernization of current degree of insurance so that Corridor Vc could be lead to ETCS Level 0. 2nd, 3rd and 4th option is concerning on ability of introducing higher levels of ETCS which are ETCS Level 1, ETCS Level 2 and ETCS Level 3. Whith evaluation of project options analysis it was concluded that each design option is reasonable, cost-effective and profitable.

Keywords: ETCS, BH railways, Corridor Vc, ETCS Level

1 Introduction

The best way to carry out modernization and standardization of infrastructure, is the introduction of ETCS security system. Strategy of introducing other ETCS on B&H's railroads on Corridor Vc in this paper is presented with four project options starting with ETCS level 0 up till level 3. Project options are divided by degree or level of ETCS insurance. The first project option involves the reconstruction of infrastructure by bringing it to the national level of security that meets ETCS Level 0. Second project option considers introducing of ETCS Level 1, while the third and fourth project options consider the possibility of upgrading the existing ETCS Level 1 to higher levels the ETCS Level 2 and Level 3.

1.1 Status line at Corridor Vc in Bosnia and Herzegovinia

Corridor Vc is setted from Budapest up tilland Ploče. At mostly it pasess through Bosnia and Herzegovina (405 + 741 km). Corridor Vc enters Bosnia and Herzegovina in Bosanski Šamac where it is connected to the track line Bosanski Šamac – Sarajevo. From Sarajevo it follows the line Sarajevo – Čapljina – state border.
Railroad line Bosanski Šamac – Sarajevo was built from April 1th until November 15th 1947. The total length of this line is 235 + 351 km. On this line there are 63 official locations, 20 of

them are stations, two of them are main, Doboj (ŽRS) and Sarajevo (ŽFBH) On this line there also are 33 train stops, 8 passing point, a junction and a state border.

Figure 1 Route of Coridorr Vc through Bosnia and Herzegovina [1]

Line Sarajevo-Čapljina, to be more accurate line Sarajevo – Čapljina – state border – Ploče began in construction in 1958 and its construction was completed in 1966. Total length of this railway line is 170 + 390 km. On this line there are 41 official locations, of which are 16 stations of which one is the main station named station Sarajevo. The railway also has 16 train stops, 7 passing point, one junction and one national border, [1].

1.2 ETCS development

As part of UIC's projects for infrastructure, largest and most important project is – ERTMS (European Rail Train Management System). Key projects, from a technical point of view, that are incorporated into ERTMS are: European Train Control System – ETCS and Global System for Mobile Communication – Railway – GSM-R. ETCS is formed with four levels, (Level 0, Level 1, Level 2 and Level 3). Goals of ETCS system, according to [2]:
· centralize management and make it more intelligent;
· reduce the costs of operation and maintenance of stationary systems;
· increase the interoperability of heterogeneous railway systems;
· increase the capacity and speed.

Functions of ETCS system:
· monitoring of (local) maximum speed;
· monitoring the correct route of trains movement;
· monitoring the direction of movement;
· monitoring the implementation of special regulations.

2 ETCS Levels

2.1 ETCS Level 0

When the vehicle that supports ETCS is being used on a line that does not support ETCS, that is Level 0 of ETCS.

2.2 ETCS Level 1

ETCS Level 1 system is a signalling system that allows the integration of ETCS equipment on existing national signalling security system that remains in operation. At this level on rail tracks Eurobalise are being installed, those transmitters take on signals from the existing track signalling via signal adapters and telegram coders (LEU – Lineside Electronics Unit)

and pass them as data to train as data that gives authorization to move and contains information on route and fixing points. Because of a point distribution of these transmitters, it is necessary that train passes over this transmitter first in order to obtain information about the next section. With cable connection of these transmitters, known as EuroLoop, constant communication with the vehicle is being held. Euroloop system implies the installation of power lines which transmit signals along the rails so that it achieves continuous coverage of the driving path, which increases safety and reliability of traffic.

Figure 2 Schematic diagram of ETCS – Level 1[1]

2.3 ETCS Level 2

ETCS – Level 2 is a system oriented to the digital radio transmission signal and train protection system. ETCS – Level 2 is a practical upgrade of ETCS – Level 1 with all the Level 1 elements but with addition of GSM-R transmitter on the locomotive, the GSM-R receiver and Radio Block Centre (RBC). Eurobalise transmitters are used at this level only as passive positional elements or so-called Electronic milestones. Between the two positional elements train defines its position by sensors. This level system is based on radio. It uses the GSM-R system, in order to continuously transferred speed limit information on the route to the vehicle. At this level Eurobalise are used as passive positioning markers.

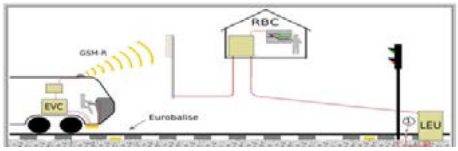

Figure 3 Schematic diagram of ETCS – Level 2 [1]

2.4 ETCS Level 3

Level 3 of ETCS system goes considerably beyond the simple signal-safety management and navigation, because it is fully implemented in the radio control system distances between trains. Fixed rail signalling devices are no longer needed. Trains define its positions the same as in Level 2 through sensors. As a participant in traffic here the train is given with the autonomy of making decisions, therefore, attention must be given to maintaining a high level of reliability. Level 3 is still under development and in Europe there are currently several experimental and pilot projects in several railroad stocks. This level supports full radio signalization, [3].

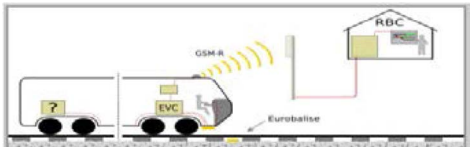

Figure 4 Schematic diagram of ETCS – Level 3 [1]

3 Strategy of ETCS implementation at Corridor Vc in B&H

3.1 Strategy of ETCS Level 0 implementation

This level of rail security will lead to increased safety and increased line capacity in facilitation of rail traffic where this level was the basis for the introduction of ETCS Level 1 ETCS as a basic level of ETCS security. The costs of reconstruction and installation of complete SS and TT security system at complete section of the Corridor Vc is estimated by former cost experience at implementation of such security levels of insurance in relation to the length and characteristics of the rail. December 30th 2009 ŽFBH signed an agreement with German company Thales Rail Signalling Solutions GmbH on support and installation of SS and TT equipment for line Konjic – Čapljina in value of €11,742,602,72 million. This section of rail is single-railed with length of 96 + 466 km and it contains 22 official locations of which is 10 stations, 4 crossing and 8 train stops.

Table 1 Economic analysis and project appraisal of ETCS implementation on B&H's rails on Corridor Vc – Option 1 – ETCS Level 0 [1]

Year	Eeconomic costs of investment (€)	Savings in maintenance costs (€)	Savings in staff costs (€)	Cost savings in traveling time for passengers and goods (€)	Savings in the costs of train operation (€)	Benefits of introduction of ETCS Level 0 (€)	Benefits and costs flow (€)
1	-26.660.000						-26.660.000
2	-26.660.000						-26.660.000
3	-26.660.000						-26.660.000
4		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
5		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
6		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
7		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
8		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
9		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
10		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
11		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
12		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
13		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
14		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
15		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
16		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
17		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
18		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
19		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
20		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
21		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
22		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
23		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
24		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
25		-550.000	624.000	11.160.000	-1.499.712	2.571.072	9.734.288
Residual value		7.998.000					7.998.000
EIRR							9,73%
NPV (5%)							40.333.206

According to this ratio deploy cost of insurance implementation and length of rail on which the implementation is being done, it can be concluded that the total cost for implementation of the SS and TT insurance on complete length of the rail at Corridor Vc (405 + 741 km) through Bosnia and Herzegovina is on average of € 50 – 60 million. Locomotive expenses or costs of installation the ETCS equipment in locomotives are around €100.000 when it comes to new locomotives. Railways in Bosnia and Herzegovina do not dispose with nither one new locomotive, so the investment costs of ETCS equipment installation in existing engines are significantly higher on average of €2.00.000 – 250.000 depending on the state of the locomotive. Considering the fact that these are relatively old locomotives costs of ETCS equipment installation per locomotive is an average of around € 200.000. From this facts it can be concluded that total cost of ETCS equipment installation for the entire locomotive fleet of 80 locomotives at Corridor Vc is around € 15-20 million. In this option, as this will be the case in other options, costs of maintainance will be analyzed for 25 years from implementation of ETCS system Level 0. So it can be concluded that the overall costs for implementation of ETCS Level 0 insurance at Corridor Vc on Bosnia and Herzegovina's rails on average is around €70 to 80 million.

3.2 Strategy of ETCS Level 1 implementation

Costs of ETCS Level 1 implementation are divided into costs that are related on equipment installation and costs of infrastructure and equipment maintenance. The costs of preparing tracks for installation of ETCS system Level 1, according to the the experience of countries in which this level is installed (Austria), are around € 2.000 – 3.000 per mile of track. B&H's railways on Corridor Vc have a length of 405+741 km therefore the costs of preparing the route for the introduction of ETCS Level 1 is to about € 1.000.000. As the cost of installation and deployment of ETCS rail security Level 1, are ranging up till € 30.000 – 300. 000 per km of railways, it is important to note that these costs far exceed the upper limit of € 300 000 when it comes to installation of the equipment in the station area, while costs on the open line are considerably less than € 30 000 per km of track. According to empirical examples (Austria), it can be assumed that costs of ETCS Level 1 equipment installation in large stations is a around € 3-4 million. In smaller stations the empirical examples come to the figure of about € 1 to 1.5 million per station, while the cost of ETCS equipment installation on train stops, junctions, level crossings, passing points, and industrial gauges are around € 200.000 – 400.000 depending on the characteristics of train stops and level crossings. While the cost of ETCS equipment installation on the open railroad on average does not exceed € 50. 000 – 80.000 per track mile. Out of 36 stations at the Corridor Vc there is total of 6 large stations: Bosanski Šamac, Doboj, Zenica, Sarajevo, Mostar and Čapljina station. This means that total cost of ETCS Level 1 equipment installation at these stations is equal of € 20 million. Cost of equipment installation at the remaining 30 stations are around € 30 million. Total cost of ETCS Level 1 equipment installation in the stations at the Corridor Vc is amount of around € 50 million. Cost of ETCS Level 1 equipment installation at other 68 official locations, industrial railtracks and a few dozens of level crossings are approximately around € 25 million. Total costs of ETCS equipment installation at the official positions is roughly around € 75 million. Finally, it can be concluded that the costs of ETCS Level 1 implementation on the BH railroads at Corridor Vc is a total of around € 100 to 120 million.

Table 2 Economic analysis and evaluation project of implementation of ETCS safety on B&H's rails at Coridorr Vc – Option 2-ETCS Level 1 [1]

Year	Eeconomic costs of investment (€)	Savings in maintenance costs (€)	Savings in staff costs (€)	Cost savings in traveling time for passengers and goods (€)	Savings in the costs of train operation (€)	Benefits of introduction of ETCS Level 0 (€)	Benefits and costs flow (€)
1	- 40.000.000						- 40.000.000
2	- 40.000.000						- 40.000.000
3	- 40.000.000						- 40.000.000
4		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
5		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
6		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
7		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
8		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
9		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
10		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
11		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
12		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
13		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
14		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
15		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
16		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
17		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
18		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
19		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
20		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
21		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
22		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
23		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
24		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
25		- 1.800.000	1.560.000	24.180.000	-9.185.736	4.138.566	14.754.264
Residual value		12.000.000					12.000.000
EIRR							9,85%
NPV (5%)							62.211.226

3.3 Strategy of ETCS Level 2 implementation

Also implementation of ETCS Level 2 costs are presumably calculated over the empirical data. For example, the costs of implementation of ETCS Level 2 system, which will be operated in Hungary by the German Siemens at line Budapest – Kelenföld – Székesfehérvár, in a distance of 65 km, costs € 53 million. According to previous experiences of countries that have implemented ETCS Level 2, on the roadlines at the Corridor Vc in Bosnia and Herzegovina at least 5 radio block centers will be need, which are placed every 50-100 km depending on the characteristics of lines and terrain on the route of the railroad. Construction and installation of radio block equipment for one radio block center will cost tens € millions. Building up and setting up the GSM-R antennas costing tens of € thousands per transmitter including signal boosters and accessories. From what is stated it can be concluded that the total cost of ETCS Level 2 implementation at the B&H's railraods at Corridor Vc in a distance of 405 + 741 km amounts to roughly € 300 million. Locomotive expenses are related to the installation of

GSM-R receiver (antenna) in the locomotives. In our case, we consider the total fleet of 80 locomotives and from the empirical data, total cost of GSM-R equipment installation to the locomotives is around € 2 million. Very expensive and high quality ETCS Level 2 equipment maintenance costs are minimized as far as possible. Thus, the annual maintenance costs should not exceed the figure of about € 2 million. Finally, ETCS Level 2 security on B&H's rails at the Corridor Vc implementation costs are total of around € 300 – 350 million.

Table 3 Economic analysis and evaluation project of implementation of ETCS safety on B&H's rails at Coridorr Vc-Option 3- ETCS Level 2 [1]

Year	Eeconomic costs of investment (€)	Savings in maintenance costs (€)	Savings in staff costs (€)	Cost savings in traveling time for passengers and goods (€)	Savings in the costs of train operation (€)	Benefits of introduction of ETCS Level 0 (€)	Benefits and costs flow (€)
1	- 110.000.000						- 110.000.000
2	- 110.000.000						- 110.000.000
3	- 110.000.000						- 110.000.000
4		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
5		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
6		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
7		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
8		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
9		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
10		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
11		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
12		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
13		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
14		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
15		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
16		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
17		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
18		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
19		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
20		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
21		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
22		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
23		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
24		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
25		- 2.450.000	3.120.000	43.524.000	- 8.248.416	9.598.896	35.945.584
Residual value		33.000.000					33.000.000
EIRR							8,46%
NPV (5%)							118.449.989

3.4 Strategy of ETCS Level 3 implementation

Level 3 is still under development and in Europe there are several experimental and pilot projects currently in several railroad stocks. ETCS Level 3 solutions for reliable train control are very complexed and not suitable for transfer and implementation to the older models of railway vehicles. As this level is still in an experimental stage, it will at some European rails be implemented in future 20 years, which tells us that the railroads in Bosnia and Herzegovina, will not take hold in the near future.

Conclusions

Option 1, which includes reconstruction and an upgrade to the existing state of the railway security with fully restored SS and TT devices that would lead rail to the ETCS Level 0and indicates the real socio-economic benefits that are result of ETCS Level 0 implementation. This project option demonstrates an acceptable net present value and economic internal rate of return of 9.73% (EIRR = 9.73%). Also the cost-benefit ratio is larger than 1 which indicates that the project is cost effective and profitable, and that its implementation needs to begin.
The second project option involves an upgrade from the existing national railway security system and ETCS Level 1 implementation. This is financially much larger project compariong to the project of ETCS Level 0 implementation but in the end there are much greater benefits from this project or from this ETCS level. This option also displays projects reasonable net present value and also an acceptable value of economic internal rate of return (EIRR = 9.85%).
The third project option requires substantially greater financial investment because ETCS Level 2 involves the usage of GSM-R system and with this level makes the European Rail Traffic Management System (ERTMS). However, by analyzing the relation between costs and benefits and the possibility of introduction of ETCS on the BH's railways at Corridor Vc is reasonable and shows a positive net present value and internal rate of return equal to 8.46% (EIRR = 8.46%).
The fourth design option involves the introduction of ETCS system Level 3, which represents the highest possible level of ETCS security. Implementation of this system in the EU is not expected before 2025. Finally, it can be concluded that the project of ETCS implementation on BH's railways at Corridor Vc is fully justified, effective and profitable.

References

[1] Marković, I.: Analysis of the possibility of introducing ETCS insurance on BH Railways on Corridor Vc, Master's thesis, Faculty of Traffic and Communications Sarajevo, 2011.

[2] Jenkins, P.: Railway Communication System GSM-R/FTN, Network Rail GB 2006.

[3] http://www.ertms.com