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Preparation of the User Requirements Specification for ETCS Level 2 System in Serbia - Experiences and Challenges

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Abstract: This paper presents a strategy implemented for preparation of the national User Requirements Specifications (URS) for European Train Control System (ETCS) with Level 2 in the Republic of Serbia. The requirements were the result of several parallel activities: gaining experience from similar implementations of the ETCS in the framework of the European TEN-T corridor railway lines, consultations about the specific technical solutions with the institutions and several suppliers of signalling equipment. The process resulted with a comprehensive specification, which will be used as a firm basis for further implementation of the ETCS system on Serbian railway network.

Keywords: Signalling; ERTMS; ETCS; TSI CCS; Requirements; Specification

1 Introduction

European Rail Traffic Management System (ERTMS) represents a set of contemporary technological solutions based on the Technical Specifications for Interoperability for Control-Command and Signalling Systems (TSI CCS). Within the ERTMS system there are two sub-systems: European Train Control System (ETCS) and Global System Mobile for Railways (GSM-R). Application level of ETCS system determines which type of trackside equipment shall be used, mode of communication between trackside and on-board equipment and processing of information within the trackside and on-board equipment in order to fulfill desired system requirements.

The railway corridors in the Republic of Serbia are not included in the list of the six major European ETCS corridors defined in clause 7.3.4 of Annex III of Technical Specifications for Interoperability for the Control Command and Signalling (TSI CCS) [1], nor in areas of special interest referred to in point 7.3.5. of the same, and the Republic of Serbia with the current status of joining the EU over an extended period is not eligible for the funds from the European Regional Development Funds, Cohesion Funds and TEN-T funds which impose installation of ETCS system in case of any upgrade of the existing signalling system.

However, preparation of the national URS for ETCS Level 2 system [2] was necessary in order to support the ongoing project for construction of new high-speed railway line Belgrade-Subotica-state border with Hungary. Although the Republic of Serbia is not yet a Member State of the European Union, the National Implementation Plan for ETCS (NIP) was prepared in parallel with URS pursuant to the article 6(4) and section 7.4.4 of the TSI CCS [1].

The main institutional stakeholders involved in the preparation of the URS were following:

•European Agency for Railways (ERA) - the European Union railway regulatory agency, with the task to regulate the European railway area and to promote the railway sector while maintaining the safety;

•"Serbian Railways Infrastructure JSC" (SRI) - Serbian national railway Infrastructure Manager;

•European Economic Interest Grouping (EEIG) ERTMS Users Group, consisting of suppliers of ERTMS equipment, thus enabling the safe, reliable, and interoperable railway network in Europe;

•Union Industry of Signalling (UNISIG) - the industrial consortium created to develop the ERTMS/ETCS technical specifications [3];

•ERTMS Deployment Management Team (ERTMS DMT) - the implementation support program unit, which provides technical and economical guidance to the stakeholders involved in ERTMS projects [4].

2 Methodology

Since the subject is regulated by both TSI CCS [2] and national regulations, the methodology for URS preparation was based on the following assumptions:

•Main functions for the ETCS system functionality regarding the interoperability shall be defined according to the requirements from reference [1], as well as according to formal approach techniques defined in the references [5–10];

•Specific national functions for the ETCS system functionality shall be defined having in mind basic requirements from references [11, 12].

The validity of the ETCS specification is usually considered as the most critical element for implementation in one country, and special caution measures were considered to secure full interoperability with requirements given in the reference [2].

Experiences that different EU member states have been identified in the previous years as a pre-requisite to deploying ETCS in their networks were implemented in order to avoid repetition of their mistakes.

3 Results

3.1 Scope of Implementation

After the wide scale consultations with all main stakeholders, it was decided that the provisions of the completed specifications shall be mandatory for all sections that belong to the Alpine-Western Balkan rail freight corridor, which represents the extension of the rail TEN-T network to the region of Western Balkan [13, 14], namely, they shall apply to the following railway line sections:

•Belgrade Centre - Sid - State border with Croatia - (Tovarnik);

•Belrade Centre - Junction “G” - Rakovica - Mladenovac - Lapovo - Nis - Presevo - State border with North Macedonia - (Tabanovce) [15];

•Nis - Dimitrovgrad - State border with Bulgaria - (Dragoman);

•(Belgrade Centre) - Resnik - Požega - Vrbnica - State border with Montenegro - (Bijelo Polje).

Figure 1. Indicative map of the ERTMS current and future deployments in Serbia

The provisions of the specifications are also mandatory for the railway section (Belgrade Centre) - Stara Pazova - Novi Sad - Subotica - State border with Hungary - (Kelebia), where the ETCS implementation was already in progress based on the intergovernmental agreement with the People's Republic of China [16], except in the points explicitly stated as an exception to these specifications, which will be the subject of a special agreement between the SRI and the Contractor.

Also, the provisions of the specifications shall be obligatory for other railway lines included in the National Implementation Plan for ETCS (see Figure 1), according to the guidelines given in the reference [17].

One of the first steps was to apply for national ETCS identification numbers (NID_C according to the definition in SUBSET 026-7 [1]), which was done in the prescribed procedure conducted by ERA. In the Table 1 are shown corresponding numbers assigned by ERA, which were officially published in the document [18].

Table 1. NID_C numbers for railway lines in Serbia currently assigned by ERA

NID_C	Country	Railway line	Confirmed by
400	Serbia	Belgrade Centre (excl.) - Stara Pazova - Novi Sad - Subotica - state border with Hungary - Kelebia (excl.)	Infrastructure of Serbian Railways JSC (IZS)
401	Serbia	Belgrade Centre - Stara Pazova - Šid - state border with Croatia -Tovarnik (excl.)	Infrastructure of Serbian Railways JSC (IZS)
402	Serbia	Belgrade Centre - Junction "G" - Rakovica - Mladenovac - Lapovo - Niš - Preševo - state border with North Macedonia - Tabanovce (excl.)	Infrastructure of Serbian Railways JSC (IZS)
403	Serbia	Niš - Dimitrovgrad - state border with Bulgaria - Dragoman (excl.)	Infrastructure of Serbian Railways JSC (IZS)
404	Serbia	Belgrade Centre (excl.) - Resnik - Požega - Vrbnica - state border with Montenegro - Bijelo Polje (excl.)	Infrastructure of Serbian Railways JSC (IZS)
405	Serbia	Belgrade Marshalling Yard "A" - Ostružnica - Batajnica and Belgrade Marshalling Yard "A" - Junction "B"- Junction "K/K1" - Resnik	Infrastructure of Serbian Railways JSC (IZS)
406	Serbia	Belgrade Marshalling Yard "A" - Ostružnica - Subotica - Horgos - state border with Hungary - Röszke (excl.)	Infrastructure of Serbian Railways JSC (IZS)

3.2 Specific National Values

3.2.1 Baseline, release and system version

In order to provide full backward compatibility between the trackside (infrastructure) and on - board (railway vehicles) components of ETCS, it was decided to implement the Baseline 3, Release 2 (SRS v3.6.0), system version X=1.0 (see Figure 2 originating from SUBSET 026-6-v3.6.0 [1]). Such solution enables that both Baseline 2 and Baseline 3 equipped trains can run on the railway lines equipped with ETCS Level 2 system.

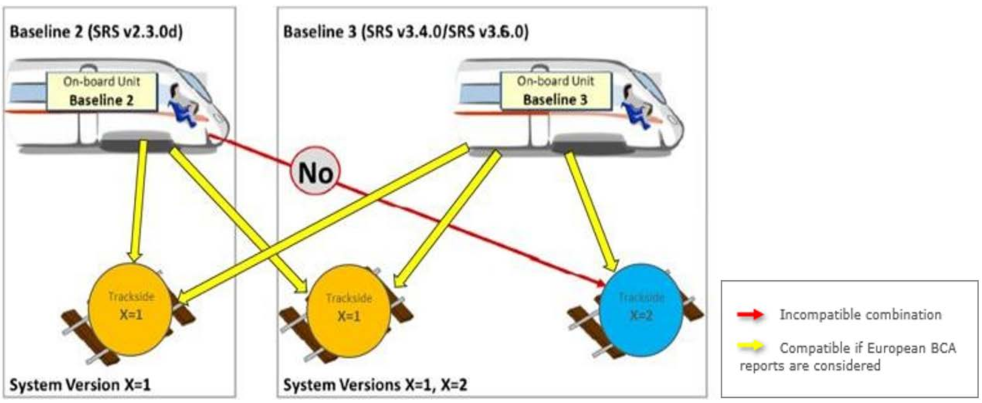


Figure 2. Compatibility between different baselines/releases/system versions

3.2.2 Absolute braking distance

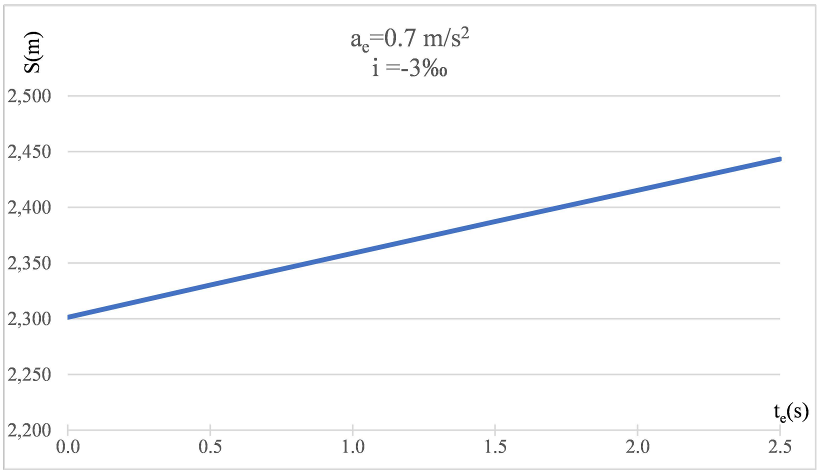
For the estimation of the absolute braking distance was used the model given in the Annex F of the standard EN 14531-1:2019 - Railway applications - Methods for calculation of stopping and slowing distances and immobilization braking - Part 1: General algorithms utilizing mean value calculation for train sets or single vehicles [19]. This model was developed based on the practical experience on the French railways (SNCF), and can be used with assumption that braking force of the train is fully established (friction braking train). The model stipulates that absolute braking distance of the train is given as:

$$s_{\text{grad}} = v_0 \cdot t_e \cdot \frac{a_e}{a_e + g_n \cdot i} + \frac{v_0^2 - v_{\text{fin}}^2}{2 \cdot (a_e + g_n \cdot i)} - \frac{a_e \cdot t_e^2 \cdot (a_e + 4g_n \cdot i)}{6 \cdot (a_e + g_n \cdot i)} \tag{1}$$

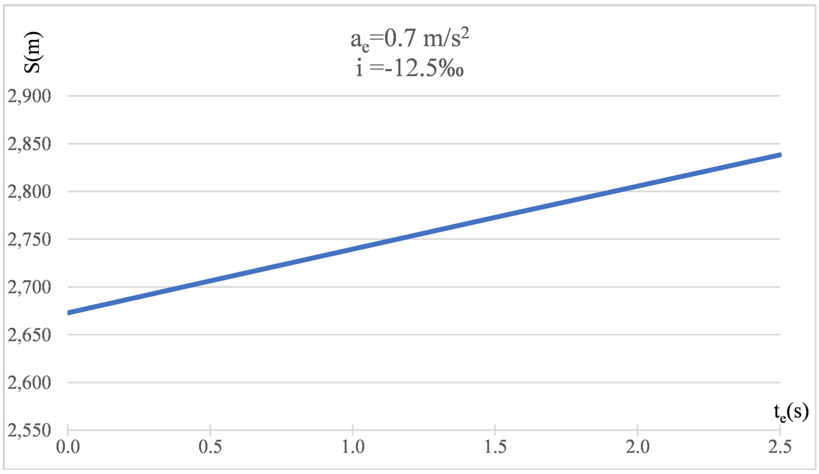
where, we have following meanings of variables:

s_{grad}: train braking distance on a given gradient of the related railway track (m)
a_e: equivalent train deceleration (m/s^2)
t_e: equivalent train driver response time (s)
v_o: initial speed of the train (m/s)
v_{fin}: final speed of the train (m/s)
g_n: standard gravity acceleration (9.81 m/s^2)
i: gradient of the related section of railway track (‰)

Using the above formulas and variations of certain parameters within the permitted limits used on the railway network of Serbia (e.g., t_e ∈(1 to 3 s), a_e ∈(0.7 to 1.1 m/s^2), i ∈(-12.5 to +12.5‰), the characteristic diagrams given in the Figure 3 and Figure 4 below were obtained, which show that in most cases the value of the braking distance does not exceed 2500 m, and therefore it was adopted as a reference one. Similar values are defined in the reference [11].

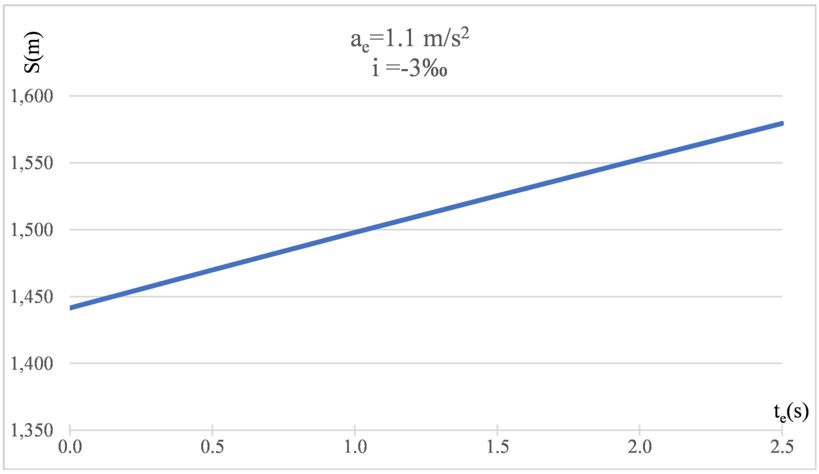


(a)

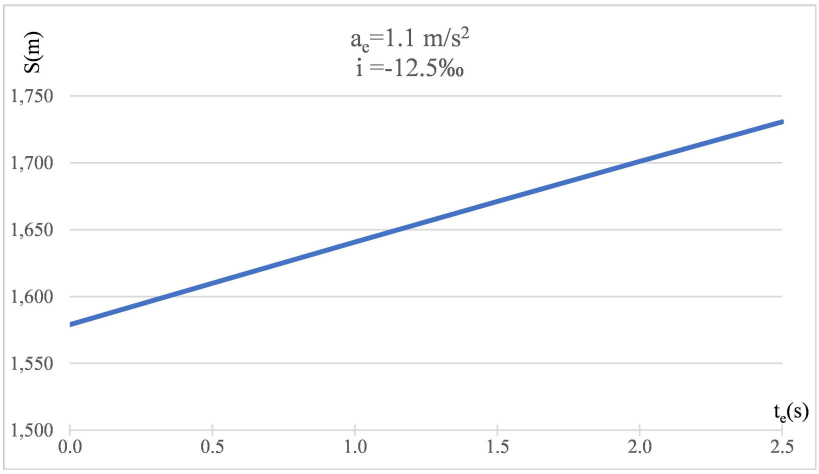


(b)

Figure 3. Absolute braking distance for a_e=0.7 m/s^2: (a) i=-3‰; (b) i= -12.5‰



(a)



(b)

Figure 4. Absolute braking distance for a_e=1.1 m/s^2: (a) i=-3‰; (b) i= -12.5‰

According to Serbian national regulations, the maximum gradient of the railway track i equals -12.5‰. Maximum train acceleration a_e for commercially available trains varies in the interval 0.7-1.1 m/s^2, and based on the experience from SNCF given in the reference [19], the driver response time shall be considered within the interval 1-3 s.

3.2.3 Maximum allowed radio failure time

Basic considerations of this issue were elaborated in the reference [20]. National parameter T_NVCONTACT represents the maximum time during which the connection between ETCS on - board equipment and Radio Block Centre (RBC) can be interrupted, when operating in Full Supervision (FS) or On - sight (OS) mode, before the ETCS on-board equipment performs further operations according to the value of parameter M_NVCONTACT. Therefore, the proper determination of these two parameters is of crucial value for providing the overall safety of the ERTMS/ETCS system.

During the period in which the ERTMS/ETCS onboard communication with the RBC is interrupted, it is not possible to receive safety-critical ETCS messages (for example, the “Emergency Stop” command). If the value of the parameter M_NVCONTACT is set to “No reaction” then all trains that are not communicating with the RBC equipment can continue their driving routes until they reach the end of their Movement Authority (MA) or until communication is re-established.

From the safety perspective this is not an optimal solution, but its actual effect on safety depends upon the number and size of the areas where interruptions in radio coverage may occur, average length of MA, and the specific train route path.

Another safety related factor is the probability that already issued MA need to be shortened or revoked. In a system based on radio communication such as Global System Mobile for Railways (GSM-R), it is mostly possible to receive a confirmation that further driving is allowed. However, the safety implications for a certain location assessment can exist, where a train may be stopped at the unsuitable location or may be forced to brake very fast.

From a safety point of view, it is important that the value of T_NVCONTACT is as less as possible, since the risk of not implementing ETCS emergency stop will be lower. The lowest time shall not be less than the minimum period between the reception of two consecutive trackside messages, since this will produce the reaction defined in the variable M_NVCONTACT.

According to the Quality of Service (QoS) requirements for GSM-R system radio coverage (paragraph 6.4.1.1. from SUBSET-093 [1]), in case that error-free period is 20 s or longer, this shall enable the coverage probability of 95%, which is satisfactory for ETCS Level 2 applications for train speeds up to 220 km/h (which includes the national speed limit of 200 km/h).

Regarding the performance point of view, the most appropriate value of the parameter M_NVCONTACT shall be "No reaction", since it will allow the train to continue to the end of the existing MA, even if the ETCS onboard equipment is disconnected from the RBC during operation in FS/OS mode. If, as mentioned above, the value "No reaction" is not appropriate, the usage of the value "Service brake" is more preferred in view of performance than that of "Train trip", since the reception of a new message before the train stops will release the brakes and allow the train to proceed with driving.

Usage of "No reaction" value for M_NVCONTACT is generally assumed only when the frequency of radio disturbances and the need to shorten or revoke the MA is very low. Main factors in consideration of using the "No reaction" value for the parameter M_NVCONTACT are following:

•Depending on the length of already set MA and extent of the radio interruption, the train might be able to proceed for a significant path, without the effect on its progress;

•In case of Emergency Stops (SUBSET-026 section 3.10 [1]), the ERTMS may not completely depend on sending the Emergency Stop messages, but also on the possibility for GSM-R voice communication (Emergency calls), and therefore the failure of the radio system or radio signal reception interruption may result with loss of both data and voice information.

In the case of an area with radio interruption, its impact on operational performance depends on the duration and space. The localized failure (for example only one radio mast), can lead to the formation of "radio-hole". If the value of T_NVCONTACT is low, not enabling the train to cross the "radio-hole", then the train can be trapped until the fail is eliminated or the train leaves the "radio-hole" with the onboard equipment set in an degraded operation mode.

From a point of view of operational performance, the most appropriate value of T_NVCONTACT shall be the largest possible one, since it will enable the railway operation less vulnerable to communication interruptions or failures. The real operational performance gain arising from larger values of T_NVCONTACT depends on the average length of MA maintained in front of the trains. It shall be noted that additional performance gain cannot be achieved by using values of T_NVCONTACT longer than time for which the MA is otherwise revoked (for example, when the train reaches the end of MA or MA expires).

On the other hand, usage of lower values for T_NVCONTACT can lead to a significant impact on operational performance, since the operation defined in the M_NVCONTACT will be executed before the receipt of potential "safe" message.

To conclude, the main principles for selection of the value of T_NVCONTACT are following:

•It shall be greater than the expected period in which the ETCS onboard equipment receives successive "safety" messages;

•It shall be greater than the period required to recover from a "radio-hole";

•It shall be greater than the time required to drive over "radio-holes", caused by failures of a single radio mast or a single base transceiver station (BTS);

•It shall not be much greater than the typical time required to reach the end/limit of authority.

The values of T_NVCONTACT and M_NVCONTACT potentially can impact on the probability for operation in a degraded modes when recovering from the previous operations specified in the M_NVCONTACT. Degraded mode operation will further have an impact on operational performance.

Based on all previous considerations, the value "Service brake" was adopted for M_NVCONTACT and value of 20 s for T_NVCONTACT was adopted.

The SRI however can also consider a different value for prospective non-high-speed railway lines (for example "Train trip" or "No reaction").

3.2.4 Localization of the eurobalises

Basic considerations of this issue were elaborated in the references [11, 21]. Balise groups of signals must be placed in the manner that every possible movement in the direction toward signal passes exactly one balise group. Adopted distances of balise group from relevant types of signals are schematically shown in Figure 5 and elaborated in more details in the Table 2.

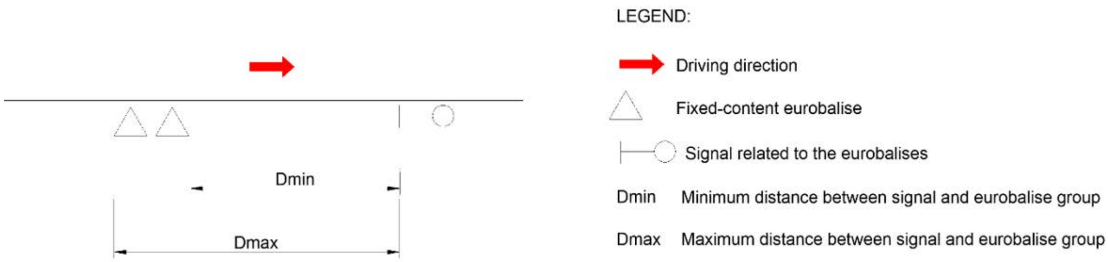


Figure 5. Position of balise group related to relevant signal

Table 2. Adopted distances of balise group from relevant types of signals

Distance type	Distance value
Distance between fixed data balise group and entry signal/caution signal	70 m ahead of the signal (first group)
250 m ahead of the signal (second group)	
Distance between fixed data balise group and exit signal/track limit signal	70 m ahead of the signal (main running line)
70 m ahead of the signal (other lines)	
Distance between fixed data balise group and automatic block signal	200 m ahead of the signal
Distance between balises within a balise group	min. 3 m - depending on the spacing between sleepers (around 60 cm)
Maximum distance between balise group and signal	Depending on the number and mutual distance between balises; it is assumed that only one additional balise is required

In certain cases (for example when leaving the ETCS zone), more than two balises in a group can be envisaged at a main signal.

3.3 Definition of the Packets and Messages to be Used

Table 3 presents an overview of distribution for applied ETCS Level 2 packets transmitted between the ETCS track-side equipment and ETCS on-board equipment, based on the definitions from reference [22].

Table 4 presents an overview of distribution of applied ETCS Level 2 messages transmitted between the ETCS track-side equipment and ETCS on-board equipment, based on the definitions from reference [23].

4 Conclusions

To summarize, prepared URS should serve as a baseline for intended development directions when it comes to ERTMS/ETCS implementation in Serbia [24, 25], including all on-going projects/contracts covering the scope.

Based on the prepared specifications, the SRI has further developed additional documents required for ETCS Level 2 implementation, including annexes considering operational scenarios and RBC operator symbol catalogue, as well as updates of the existing Signalling Rulebook [26] and Traffic Regulation Rulebook [27] in respect to ERTMS/ETCS operation.

The future updates of these URS for ETCS shall include, inter alia, the requirements for ETCS Level 1, as well as eventual updates regarding new requirements from updated TSI CCS [2], whose adoption is expected during 2023.

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Data Availability

The data supporting the research results are included within the article or supplementary material.

Conflicts of Interest

The author declares no conflict of interest.

Table 3. Applied ETCS Level 2 packets

Packet No	Packet name	Applied in the Republic of Serbia for the ETCS Level 2
0	Virtual Balise Cover marker	
2	System Version order	
3	National Values	X
5	Linking	X
12	Movement Authority Level 1	
13	Staff Responsible distance information from loop	
15	Movement Authority Level 2/3	X
16	Repositioning Information	
21	Gradient Profile	X
27	International Static Speed Profile	X
39	Track Condition Change of Traction Power	
40	Track Condition Change of allowed current consumption	
41	Level Transition Order	X
42	Session Management	X
44	Data used by applications outside the ERTMS/ETCS system	X
45	Radio Network registration	X
46	Conditional Level Transition Order	X
49	List of balises for shunting Area	X
51	Axle Load Speed Profile	X
52	Permitted Braking Distance Information	
57	Movement Authority Request Parameters	X
58	Position Report Parameters	X
63	List of Balises in Staff Responsible Authority	
64	Inhibition of revocable TSRs from balises in Level 2/3	
65	Temporary Speed Restriction	X
66	Temporary Speed Restriction Revocation	X
67	Track Condition Big Metal Masses	
68	Track Condition	X
69	Track Condition Station Platforms	
70	Route Suitability Data	
71	Adhesion Factor	X
72	Packet for sending plain text messages	X
76	Packet for sending fix text messages	
79	Geographical Position Information	X
80	Mode profile	X
88	Level Crossing Information	
90	Track ahead free up to Level 2/3 transition location	
131	RBC transition order	X
132	Danger for shunting information	X
133	Radio in-fill area	
134	End Of Loop Marker Packet	
135	Stop shunting on desk opening	
136	Infill location reference	
137	Stop if in staff responsible	X
138	Reversing area information	
139	Reversing supervision information	
140	Train running number from RBC	
141	Default gradient for temporary speed restriction	X
143	Session Management with neighbouring Radio Infill Unit	
145	Inhibition of balise group message consistency reaction	
180	Lowest Supervised Speed within Movement Authority display toggle order	
181	Generic Limited Supervision function marker	
254	Default balise, loop or radio-infill unit information	X
255	End of information	X

Table 4. Applied ETCS Level 2 messages

Message ID	Message name	Applied in the Republic of Serbia for the ETCS Level 2
2	Staff Responsible Authorization	X
3	Movement Authority	X
6	Recognition of exit from Trip mode	X
8	Acknowledgement of Train Data	X
9	Request to Shorten MA	X
15	Conditional Emergency Stop	X
16	Unconditional Emergency Stop	X
18	Revocation of Emergency Stop	X
24	General message	X
27	Shunting Refused	X
28	Shunting Authorized	X
32	RBC/RIU System Version	X
33	MA with Shifted Location Reference	X
34	Track Ahead Free Request	X
37	In-fill MA	
39	Acknowledgement of termination of a communication session	X
40	Train Rejected	
41	Train Accepted	X
43	Start of Mission position report confirmed by RBC	
45	Assignment of coordinate system	X
129	Validated Train Data	X
130	Request for Shunting	X
132	MA Request	X
136	Train Position Report	X
137	Request to shorten MA is granted	X
138	Request to shorten MA is rejected	X
146	Acknowledgement	X
147	Acknowledgement of Emergency Stop	X
149	Track Ahead Free Granted	X
150	End of Mission	X
153	Radio in-fill request	
154	No compatible version	X
155	Initiation of a communication session	X
156	Termination of a communication session	X
157	Start of Mission Position Report	X
159	Session Established	X

References

[1] DOMAINS-Infrastructure, “Control command and signalling TSI,” *European Union Agency for Railways*. https://www.era.europa.eu/domains/technical-specifications-interoperability/control-command-and-signalling-tsi_en

[2] JSC, “User requirements specifications for ETCS level 2 system on railway network in Republic of Serbia v1.2,” *Serbian Railways Infrastructure, Republic of Serbia*, 2020.

[3] UNIFE, “UNISIG - an industrial consortium to develop ERTMS/ETCS technical specifications,” *Factsheet*, 2021. https://www.ertms.net/wp-content/uploads/2021/07/ERTMS_Factsheet_8_UNISIG.pdf

[4] E. D. M. Team, “Examples of variations and rules hindering ERTMS deployment, version 4.0,” *European Union*, 2016. https://transport.ec.europa.eu/document/download/2df6a830-3a9f-47a9-8757-522c0ffd3e10_en?filename=ertms_examples_of_variations_and_rules_hindering_ertms_deployment.pdf

[5] E. Krmac and B. Djordjević, “An evaluation of train control information systems for sustainable railway using the analytic hierarchy process (AHP) model,” *Eur. Transp. Res. Rev.*, vol. 9, no. 3, p. 35, 2017. https://doi.org/10.1007/s12544-017-0253-9

[6] M. Ghazel, “Formalizing a subset of ERTMS/ETCS specifications for verification purposes,” *Transport Res.*

Part C: Emerg Technol., vol. 42, pp. 60–75, 2014. https://doi.org/10.1016/j.trc.2014.02.002

[7] D. Basile, M. H. ter Beek, A. Ferrari, and A. Legay, "Exploring the ERTMS/ETCS full moving block specification: An experience with formal methods," *Int J. Softw Tools Technol Transfer*, vol. 24, no. 3, pp. 351–370, 2022. https://doi.org/10.1007/s10009-022-00653-3

[8] A. Ferrari, F. Mazzanti, D. Basile, and M. H. ter Beek, "Systematic evaluation and usability analysis of formal methods tools for railway signaling system design," *IEEE T. Software Eng.*, vol. 48, no. 11, pp. 4675–4691, 2021. https://doi.org/10.1109/TSE.2021.3124677

[9] P. James, A. Lawrence, M. Roggenbach, and M. Seisenberger, "Towards safety analysis of ERTMS/ETCS level 2 in real-time maude," *In Formal Techniques for Safety-Critical Systems: 4th International Workshop, FTSCS 2015, Paris, France*, pp. 103–120, 2016. https://doi.org/10.1007/978-3-319-29510-7_6

[10] A. Chiappini, A. Cimatti, L. Macchi, O. Rebollo, M. Roveri, A. Susi, S. Tonetta, and B. Vittorini, "Formalization and validation of a subset of the European train control system," *In Proceedings of the 32nd ACM/IEEE International Conference on Software Engineering-Volume 2, New York, NY, USA*, pp. 109–118, 2010. https://doi.org/10.1145/1810295.1810312

[11] DB Netz AG, "Grundsätze zur erstellung der ausführungsplanung PT1 für ETCS level 2, version 1.1," *Deutsche Bahn AG, Germany*, 2017.

[12] J. Trinckauf, U. Maschek, R. Kahl, and C. Krahl, "ETCS in Deutschland," *PMC Media House GmbH Leverkusen*, 2020.

[13] CONNECTA-TRA-CRM-REG-03, "Strategic framework for implementation of ITS on TEN-T core/comprehensive network on the WB6 - final report," *TA to Connectivity in the Western Balkans - EuropeAid/137850/IH/SER/MULTI*, 2018.

[14] TEN-T-Report-2022_s, "Development of indicative TEN-T extensions of the comprehensive and core network in Western Balkans," *Transport Community*, 2022. https://www.transport-community.org/wp-content/uploads/2022/11/TEN-T-Report-2022_s.pdf

[15] Stakeholder-Engagement-Plan-1, "Reconstruction and modernization of the railway line belgrade - Nis up to speed of 200 km/h, preparation for feasibility study, ESIA and preliminary design," *EU Project Preparation Faciuty*, 2022. https://www.eib.org/attachments/registers/159127057.pdf

[16] D. Stojanović, E. Jovičić, and N. Stanisavljević, "The role and significance of Chinese investments in the modernization of railway infrastructure in Serbia," *In Opportunities and Challenges for Multinational Enterprises and Foreign Direct Investment in the Belt and Road Initiative*, pp. 194–216, 2022. https://doi.org/10.4018/978-1-7998-8021-9.ch009

[17] EIM-ERTMS-guide, "European rail infrastructure managers (EIM): ERTMS - A guide for stakeholders," *EIM*, 2020. https://eimrail.org/wp-content/uploads/2020/02/EIM-ERTMS-guide.pdf

[18] ERA_ERTMS_040001, "Assignment of values to ETCS variables, version 1.33," *European Union Agency for Railways*, 2023. https://www.era.europa.eu/system/files/2023-02/ETCS%20variables%20and%20values.pdf

[19] UNE EN 14531-1:2016+A1:2019, "Railway applications - Methods for calculation of stopping and slowing distances and immobilization braking - Part 1: General algorithms utilizing mean value calculation for train sets or single vehicles," *European Standards*, 2019. https://www.en-standard.eu/une-en-14531-1-2016-a1-2019-railway-applications-methods-for-calculation-of-stopping-and-slowing-distances-and-immobilization-braking-part-1-general-algorithms-utilizing-mean-value-calculation-for-train-sets-or-single-vehicles/

[20] RIS-0708-CCS Iss 1, "ERTMS/ETCS national values," *Rail Safety and Standards Board*, 2019. https://www.rssb.co.uk/standards-catalogue/CatalogueItem/RIS-0708-CCS-Iss-1

[21] 23 EUG GDL Balise_Engineering, "Engineering guideline - Balise engineering for L2 and L3, version 1.0," *ERTMS Users Group*, 2019. https://ertms.be/sites/default/files/ESG%20working%20Group/23%20EUG%20GDL%20Balise_Engineering%20v1.0.pdf

[22] UNISIG SUBSET 026-7, "System requirements specifications - Chapter 7. ERTMS/ETCS language, version 3.6.0," *ERA * UNISIG * EEIG ERTMS Users Group*, 2023. https://www.era.europa.eu/system/files/2023-01/sos3_index004_-_subset-026_v360.zip

[23] UNISIG SUBSET 026-8, "System requirements specifications - Chapter 8. messages, version 3.6.0," *ERA * UNISIG * EEIG ERTMS Users Group*, 2023. https://www.era.europa.eu/system/files/2023-01/sos3_index004_-_subset-026_v360.zip

[24] MGSI, "Investment plan," *Ministry for Construction, Transportation and Infrastructure of Serbia*, 2019. https://www.mgsi.gov.rs/sites/default/files/Investicioni%20Plan%20MGSI%20septembar%202019%20ENG%20tekst%20.pdf

[25] Serbia Railway Sector Modernization, "Phase 1 of the multi-phase programmatic approach- serbia railway sector modernization," *Ministry for Construction, Transportation and Infrastructure of Serbia*, 2020. https://www.mgsi.gov.rs/sites/default/files/WB%20IBRD_SRSM%20Project_ESMF_EN_December.pdf

[26] Pravilnik_o_vrstama_signala, “Directorate for railways: Signalling rulebook,” *www.raildir.gov.rs*, 2020. https://www.raildir.gov.rs/doc/podzak/Pravilnik_o_vrstama_signala.docx

[27] Saobracajni_pravilnik-09-22, “Directorate for railways: Traffic regulation rulebook,” *www.raildir.gov.rs*, 2022. https://www.raildir.gov.rs/doc/podzak/Saobracajni_pravilnik-09-22.docx