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DIGITALIZATION IN RAILWAY TRANSPORT AS A FACTOR FOR IMPROVING THE QUALITY OF THE OFFERED RAILWAY SERVICE

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Abstract

Over the last 20 years, digitalization has been advancing at an extremely rapid pace in all sectors of the economy, with rail being no exception. In today's world, digital technologies manage the railways – the ERTMS system, the ETCS system, the train operation management system, ticket reservations, the exchange of information between railway administrations – are technologies that offer much more added value to the sector. Digitalization and ecology are the key to the competitiveness of rail transport compared to other modes of transport. Improving the efficiency of the organization of the transport process and customer service are the challenges that will be overcome with the implementation of digitalization and its application.

The research of the quality of the offered transport service is fundamental for the sustainable development of the railway industry and its impact on the modal shift to railway transport. Whether national, international, suburban passenger or freight, the latter has significant environmental advantages over other modes of transport. Strategic planning through the introduction of digital technologies will enhance the modal shift to rail transport, which is key to the decarburization of the entire transport industry. The sustainable development of railway transport through the digitalization of the offered transport services contributes to the growth of other industries in the economy.

Keywords: digitalization, railway transport, railway infrastructure, automation and signalization systems

JEL: R42, Q49

Introduction

Digitalization is crucial to the competitiveness of railway transport and is therefore a top priority in the EU's policies. In the European Year of Rail (2021) programs for providing a solid political framework have been initiated, and research in infrastructure and uniform standards related to the effective use of data has been funded. As a result, all participants in the railway sector have been given a chance to improve their effectiveness and provide better services to their

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potential customers. Interested parties view all the changes that will occur through digitalization as an opportunity in terms of the benefits they provide them with.

The challenge is that the endeavor will require substantial financial resources, changes in the way of thinking, new business models, as well as addressing the issue of cyber security. Ultimately, overcoming these hurdles will help strengthen the role of railway transport by improving its competitiveness and effectiveness.

The projects carried out by the National Railway Infrastructure Company are the subject of research, and the digitalization of railway services through the incorporation of railway traffic regulation systems is the object of research. The main thesis of the presented work is that the fundamental problems in the organization of railway traffic can be solved through digitalization. Railway transport can be much more effective and profitable when carrying out its freight activities with improved transmissivity and increased operating parameters when it comes to the safety, reliability and security of transport operations based on digitalization. The research goal is to analyze the fundamental systems in railway traffic regulation in the context of digitalization and the requirements for the stable development of the sector and how their incorporation improves the quality of the supplied railway services. Thus, the set goal will be achieved by solving the following problems:

- Use the analysis of the ERTMS, ETCS, GSM-R and TWMS[2] systems as the basis to substantiate the necessity for their faster incorporation along the country's railway network;
- Assess how the use of these systems helps improve speed, compliance with traffic timetables and especially the utilization of the capacity of the railway infrastructure;
- Analyze the projects which the National Railway Infrastructure Company carries out and how their realization will improve the quality of the proposed railway infrastructure.

The Nature and Significance of Automation Systems and Signaling Systems in Railway Transport

The means for mechanization and automation of railway traffic and maneuverable work are various devices, instruments and installations used for regulating arrows, signals and vehicle movement. They are primarily designed to guarantee the safety and security of train traffic and maneuverable work; their more advanced counterparts also contribute to the achievement of significant economic and social effects. They are also known as the Insurance Equipment of Railway Infrastructure, which is a combination of devices and systems that regulate the remote control and dependency of the signals, controlled sections,

[2] Train Work Management System.

arrows and level crossing devices, ensuring traffic safety in operating points and station-to-station blocks (Vassilev, 2012).

The various member states of the EU had their own individual signaling systems and technical specifications in the early 1990s. Unfortunately, they were not interoperable, which would create difficulties for the movement of trains through different countries. Because of this, trains would either have to be equipped with several systems or the rolling stock and locomotive brigade would have to be replaced. All of this would be accompanied by additional costs related to train operations and traffic delays, which in turn would place railway transport at a disadvantage in its competition with motor transport (Minkov, 2019). In order to resolve these issues, the EU created a unified system for control, regulation, signalization and communication in the early 2000s. To achieve interoperability[3] between the railways of European countries with the purpose of facilitating the movement of trains among them and reducing the number of stops at border posts, as well as ensuring an equal level of technical safety, a unified system for regulating railway traffic – ERTMS (European Rail Traffic Management System), was adopted for implementation. Its integration solved this fundamental problem with the various national signaling and automation systems, resulting in the creation and development of the so-called unified railway area in Europe. The use of this system ensured uniform standards in the unimpeded movement of trains through various countries, which resulted in saving time and reducing operating costs. Additionally, interoperability between various railway administrations, the quality of provided services and cross-border railway transport were improved. The ERTMS system includes two primary subsystems – the European Train Control System (ETCS) and the railway radio system known as the Train Dispatch Connections System (TDCS) and GSM-R (Global System for Mobile Communication – Railway), whose purpose is to directly relay and receive business messages and service orders, as well as to prevent accidents. The incorporation of the Train Work Management System (TWMS) helped improve the transmissivity of the railway network towards an appealing frequency of transport services. These systems are designed to standardize the various types of signaling in railway transport and speed control systems that exist in the individual railway administrations of European countries. That way, cross-country passage will be facilitated as much

[3] The necessity for achieving interoperability (unification) is enforced due to the fact that various systems for train traffic regulation, traction power supply and radio communication systems are in operation in European countries. Additionally, each country uses its own rules for railway operation and safety requirements, as well as its own systems for training and licensing train personnel. These conditions impede the direct transit of trains through the territory of several countries and increases the number of stops at border stations grows.

as possible, without any explicit complications of technological and normative nature, and the security, safety, control and regulation of trains will be ensured.

These systems provide significant technical and technological innovations which turn them into an innovative system that combines interoperability and safety, modern technological and technical solutions, signal insurance and information systems that lead to harmonization and standardization with a view to a common European policy.

In summary, we can say that all of these systems (ERTMS, ETCS, TWMS) work by identifying the condition and status of the railway network, subsequently transmitting a "movement authorization" to a given train by determining the distance that the train is permitted to traverse and providing data pertaining to the road ahead such as speed limits, curves and slopes. An on-board computer uses this information, along with the data regarding the train such as braking ability, to compute the speed limit, as well as the safe brake profile when the train approaches the end of its movement authorization. A special (odometric) on-board system observes the road from the train's position, providing an option to verify whether the movement authorization has expired, and, if the speed limit is exceeded, action is automatically taken to regulate the train's velocity. On-board functionality, which is provided by the ETCS, has three levels of development.

At **the first level**, trains receive movement authorization from existing traffic signals through manageable and powered devices (Eurobalises). In essence, it is a standardized system of automatic locomotive signals which contains the primary functions for guaranteeing the safe movement of trains. However, this level does not provide complete compatibility, the speed limit is 130 km/h, transmissivity is not allowed, and advancing to a higher level requires considerable expenses, which is not particularly helpful in the long run (Vasilev, Kirilova, 2015).

The second level is much more forward-looking and economically effective. Trains receive movement authorization from the control center through the GSM-R radio communication system which is standard for railways (Franekova, 2010). Trains determine their location (with the help of Eurobalises) and transmit it to the control center which keeps track of all trains along the railway network and sets their speed in accordance with local conditions and the position of other trains. There are no speed limits. Information inside the locomotive is updated constantly and the human factor is eliminated for the purpose of safe movement. The system does not need track circuits, axis counters and other devices. Railway crossings can also be managed from the control center. Complete interoperability is achieved, transmissivity is increased, and operating costs are reduced. It is believed that one control center is sufficient for managing the entire railway network of Bulgaria.

The third level is an advanced version of the second level, where trains determine their location through the global positioning system (GPS). The control center moves the trains, along with a safe zone (a mobile block-area) around them. The length of the zone changes depending on speed. Maximum transmissivity of the railway infrastructure is achieved. Train signals and other insurance equipment devices along the railroad are completely removed. Only the arrow apparatus which is managed by the control center remains. This level ensures the highest degree of freight effectiveness, security and safety.

As part of the on-board equipment of locomotives, the ETCS system can be used along all railroads – secondary motorways, suburban, high-speed, etc. At present, the first and second level of the system are primarily used in a number of European countries, whereas the third level is still in development (Koruni, 2020).

Communication functionality is carried out through the GSM-R digital system for mobile communications in railway transport. This system is specially designed for railway transport on the basis of the global standard and is capable of carrying out all colloquial tracks and data transfer, thus achieving train radio connection through radio control of train traffic and station sound systems. The goal is to improve the speed and safety of passenger and cargo freights (Vassilev, Kirilova, 2015).

Unlike the aforementioned system, the purpose of the Train Work Management System is to automate the processes of planning, prognosticating, managing and reporting the work of the train staff. Additionally, this system carries out other tasks that can be summarized in the following directions (NRIC, 2021):

- calculating infrastructure taxes, which allows statistics to be kept and analyses to be made based on the obtained data;
- improving the quality of supplied railway services by reducing the amount of time necessary for train processing;
- optimizing the transit of international trains;
- increasing the transmissivity of the railway network;
- improving operating parameters in terms of the safety, reliability and security of transport operations;
- reporting the amount of carried out train work in real time.

The digitalization of railway transport through these systems and the realization of these activities will ensure freight safety, prevent traffic accidents, and reduce maintenance costs for the infrastructure and the rolling stock. All of these signaling and automation systems guarantee equal access to the railway infrastructure, concrete and correct collection of infrastructure taxes, as well as safe management of the railway network capacity.

Analyzing the Development of Digitalization in Bulgaria's Railway Transport

The digitalization of Bulgaria's railway transport has not affected all types of transport equally. Although railway transport has been carrying out passenger and cargo freights in Bulgaria since the late 19th century and has been a leading participant in the industrial revolution of the 20th century, over the last 50 years it has fallen behind in terms of its innovative development compared to other types of transport. With their rapid technological advancements, motor transport and air transport have taken the leading position in technological innovations away from railways. With the development of digitalization in industrial and economic sectors, railway transport has failed to respond adequately to these needs and has not encompassed all regions in the country equally. According to interested parties, this type of transport has not adapted to the rapidly changing conditions in trade and passenger transportation. Nowadays the digitalization of railway transport is a necessary step in its future development. In order to improve productivity, operation and maintenance, railway carriers and infrastructure enterprises need to view digitalization as leverage to improve their effectiveness, energy output, and especially to reduce operating expenses. This in turn will make railway transport more competitive in comparison to other types of transport. Digitalization is a new element of the competitiveness of companies in the transport sector, as well as a vital condition for the improvement of the said sector (Arnaudov, 2021).

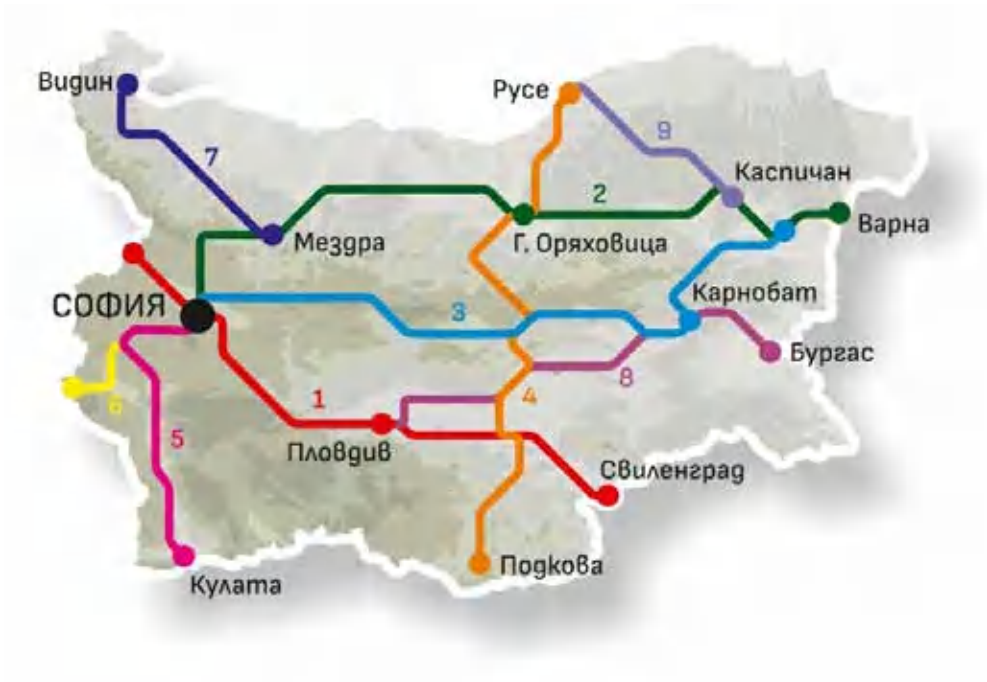
The incorporation of these systems for regulation of railway traffic and trains is mandatory for all EU member states. The new directive 2016/797 (EU) (EUR-Lex, 2016) determines the conditions for achieving interoperability within the European Union's railway system which will lead to determining the maximum level of technical harmonization; this, in turn, will help facilitate, improve and develop international railway transport services, even with third countries. This will also contribute to the gradual establishment of the internal market for equipment and services for building, renewing, updating and operating the EU's railway system. The transposition of legislation in Bulgaria depends on the National Railway Infrastructure Company (NRIC) and national carrier BSR "Passenger Freight"; additionally, there are procedures for encouragement during appropriate and timely conversions. As the body in charge of railway infrastructure, the NRIC has a plan to incorporate ERTMS, whereas the BSR has respectively formulated a plan for replacing the rolling stock which needs to be equipped with the ETCS and GSM-R systems. The plans have undergone updates over the years, the most recent one being from this year. The future infrastructure is outlined in the plan, and railway lines will have to be equipped with ERTMS in accordance with regulations after they have been modernized or reconstructed. BSR "Passenger Freights" has already put the Siemens Smartron

rolling stock, which is equipped with second-level ETCS and GSM-R for voice and data communication, into operation (BDZh, 2021).

The main railway lines from the trans-European railway network in Bulgaria are listed below (True North, 2021):

1. Dragoman – Sofia – Plovdiv – Svilengrad – Line 1;
2. Plovdiv – Burgas – Line 8;
3. Sofia – Blagoevgrad – Kulata – Line 5;
4. Sofia – Mezdra – Vratsa – Vidin – Line 7;
5. Sofia – Mezdra – Gorna Oryahovitsa – Varna – Line 2;
6. Ruse – Stara Zagora – Dimitrovgrad – Podkova – Line 4.

The main railway tracks in Bulgaria are presented in Figure 1.



Source: BSR Ltd.

Figure 1: Bulgaria's Railway Network

The following map presents lines equipped with ETCS and GSM-R, as well as lines which are due for modernization and/or rehabilitation.

Source: SOE NRIC

Figure 2: Primary railroads from the railway network which have been equipped with automation and signalization

As the two figures listed above show, Bulgaria's railway network is well developed in terms of territorial coverage (41 km per 1000 square km) and has a large share of electrification (80%). The doubled sections along the railway network comprise approximately 900 km, which is about 23% of the total deployed length of the railway lines (NRIC, 2021). In order to increase effectiveness, safety and speed, the NRIC has invested in the incorporation of ERTMS along the railway network. One such section is Septemvri – Plovdiv – Svilengrad (200 km), where the road-bed allows trains to move at 160 km/h. Another railway network section equipped with ERTMS is Mihaylovo – Burgas (210 km). At the same time, the NRIC is working on a multitude of other projects related to improving the parameters of the railway network. These projects include:

1. Modernizing the Sofia – Elin Pelin – Kostenets – Septemvri railway section – 100 km

This section is divided into three parts: Sofia – Elin Pelin (24), Elin Pelin – Kostenets (50) and Kostenets – Septemvri (26). The road-bed is among the main railway junctions and holds vital regional, economic and strategic significance as a line that connects the two largest industrial cities in Bulgaria.

2. Modernizing the Skutare – Mihaylovo railway line – 67 km

The road-bed of this section is part of the Sofia – Burgas line, and its modernization will lead to improvements in speed and significantly reduced travel time between the capital and the seaside.

The realization of the two aforementioned projects is a top priority in the national railway system, and its rehabilitation will help improve the quality of the provided services and reduce transport expenses. The higher speed and the improved quality of the services will help make railway transport more competitive compared to other types of transport.

3. Modernizing the Sofia – Voluyak – Dragoman – Kalotina railway line – 54 km

The modernization of this section, which is part of International Trans-European Corridor 10, will improve the connectivity between the Serbian and Turkish borders. The incorporation of ERTMS along the entire direction of this corridor will considerably improve travel time between Serbia and Turkey.

The main goal of these projects is achieving the characteristics of the railway infrastructure in accordance with Regulation (EU) № 1315/2013 (EUR-Lex, 2013) for the Trans-European Transport Network, as well as customers' needs for transport services for effective transport. Eliminating the crossings between railway lines and other types of ground transport at the same level will ensure that the requirements aimed at the railway infrastructure for safety and reliability in the regular operation of railway lines will be achieved. The realization of these projects will remove the speed and capacity limits of railway and motor traffic flows, improve the ecological situation and preserve the environment by reducing harmful gas emissions as well as the negative impact of passing railway lines on urbanized territories. The successful realization of the projects will contribute to the achievement of the commitments Bulgaria has made in regards to developing the railway infrastructure, reaching European standards in accordance with EU policies, and the stable development of trans-European transport networks.

The specific objectives in the realization of the presented projects include improving the quality of the Sofia – Burgas railway line and expanding railway transport traffic by:

- reducing travel time by increasing the speed limit to 160 km/h, as well as eliminating crossings at the same level;
- reducing operating expenses of service providers by eliminating crossings at the same level, renewing the contact network and reconstructing arrow development;
- transferring cargo freight from highway to railway transport with benefits for passengers and the community by reducing costs and expanding railway

transport traffic as a result of increasing speed limits in rehabilitated and modernized railway sections.

The integration of ERTMS along the Kalotina – Sofia, Sofia – Septemvri and Skutare – Mihaylovo railway lines will help improve traffic safety. The full realization of the modernization and rehabilitation of these sections will help increase the capacity of the infrastructure by improving the operational parameters and introducing modern methods for controlling train traffic, reducing unit costs in the railway network by reducing the energy intensity of transport, reducing the staff, increasing the appeal of railway transport by improving the quality of services in the field, creating conditions for servicing people with limited mobility, creating conditions for the transportation of passengers and cargo, improving the quality of services and reducing travel time, and guaranteeing a higher standard of the railway network by introducing modern regulation systems such as ERTMS / ETCS, GSM-R, SCADA (NCIR, 2021).

Conclusion

The perspectives for railway transport involve improving the comfort and culture of service, as well as increasing the speed and frequency of train traffic. These indicators can be improved by modernizing the railway infrastructure and incorporating new generations of automation systems and signaling systems (Dimitrov, 2019). The purpose of the digitalization of railway transport through the incorporation of ERTMS, ETCS, GSM-R and TWMS is to assist the creation of an unbroken European railway system, replacing the various national train regulation systems in Europe. Additionally, all of these systems facilitate high-speed railway transport, thus allowing the expansion of the capacity of railways and improving safety, reliability and security.

As a result of the conducted analysis, the following essential trends in the development of railway transport through its digitalization can be outlined:

- safer and more reliable railway transport will be guaranteed;
- the number of accidents and emergencies caused by the railway infrastructure will be reduced;
- competitive speed along the railway network in comparison to motor transport will be achieved and business-oriented railway routes will be developed;
- improving the effectiveness and quality of transport services will increase the competitiveness of railway transport;
- improved competitiveness will result in satisfying the needs of customers who use the provided high-quality service – security, ecological compatibility and reliability;
- the capacity of the existing railway infrastructure will be optimized.

ERTMS, ETCS, TWMS and GSM-R must be put into operation along the primary transport corridors passing through the territory of our country by 2030. These projects must be realized within the set deadlines through persistence and the combined efforts of the NRIC, the BSR and especially the Ministry of Transport, regardless of this challenge. The digitalization of railway transport will result in improved travel time which is crucial to attracting passengers. The incorporation of these systems for automation of train traffic will automate the processes of planning, prognosticating, managing and reporting train traffic. The purpose of these systems is to improve the quality of supplied transport services by reducing the time necessary for train processing, as well as the transit of international trains, and increasing the transmissivity of the railway network. This will ensure freight safety and reduce traffic and maintenance costs for the infrastructure and the rolling stock.

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