Digitalization of Railways – ICT Approach to the Development of Automation

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Contribution to the state of the art

DOI: **10.7251/JIT1901017A** UDC: **656.2:[621.313:681.5**

Abstract: The concept of digital railway is defined in the European Initiatives, which started in 2016. The basis for this technical development and improvement plan is the Shift²Rail and the *Roadmap for Digital Railways*, presented by the Community of European Railways and Infrastructure Managers (CER), the International Rail Transport Committee (CIT), the Association of European Rail Infrastructure Managers (EIM), and the International Union of Railways (UIC).

Keywords: ATO, automatic train operations, digital railway, ERTMS, ETCS.

Introduction

There are numerous options for modernizing the railways using digital technologies in train management [1], [5-7]. In the context of digitization, train management involves automated traffic management (including support for decision-making and train speed regulation), signal transmission to the machine driver's cab (European Train Control System - ECTS), Automated Train Operations (ATO), related advisory systems (CDAS), and appropriate supporting telecommunication network [2], [4].

The introduction of digital solutions will increasingly be the focus of modern and future efficient railways. It will improve connectivity and help people move faster and safer. The current traditional signaling infrastructure is gradually becoming history with increasing security risks and possible delays [3].

State and Development Concepts

Digital technologies, such as the transmission of signal signs to the cab of the machine operator and intelligent railway traffic management systems, are becoming more and more important in raising the capacity of the existing rail network, and in particular to meet the prospective growth needs.

The European Railways have made a number of recommendations based on the transport needs and possibilities of the modern industry in the area of signaling and management of rail traffic with the aim of introducing digital signalization and operational technology (Table 1).

The recommendations were based on the conclusion that improvements in signaling and traffic control technology are needed to expand the network of railroads of the highest class. The idea is to speed up the development of the European Train Control System (ETCS), as well as traffic management software and driver support.

The introduction of digital signaling technology suggests a greater dependence on a reliable mobile network. This initiates the need to build a SWIFT (Superfast Wi-Fi In Carriage for Future Travel) project, which will be a good example of a harmonized partnership in technology, railways and mobile networks.

The SWIFT project is designed to provide free Wi-Fi services for travelers through a dedicated infrastructure installed along the railway network. It

Table 1. *Global trend of information development*

Research and innovative solutions under development	IPID 2020	EU White Paper	Shift 2Rail	US FRA Strategic Plan
Increased safety based on intelligent systems	☑	☑	☑	
Reduction of risks related to the human factor	☑			☑
Increased business efficiency and streamlining of logistics	☑	☑	☑	☑
Development of multimodal transportation	☑	☑	☑	
Harmonization of service-related requirements. “One stop"	☑	☑		
Development of virtual and cloud-based client services	☑	☑	☑	
Computerization and digitalization of traffic management processes	☑	☑	☑	☑
High-speed traffic development	☑	☑	☑	☑
New rolling stock	☑	☑	☑	☑
Increased energy efficiency	☑	☑	☑	☑
New power plants. New types of energy resources	☑	☑	☑	☑
Focus on rational environmental management	☑	☑		
Infrastructure development	☑	☑		☑
Unmanned technologies	☑		☑	☑

**IPID – Investment Projects Implementation Department*

will be used by existing Network Rail Telecoms networks to provide good connectivity and speed for the user.

Projects for the introduction of digital signalization and management technology should be jointly developed by the owners of the railway infrastructure in partnership with the appropriate companies for the transport of passengers and goods.

Development Rights

Digital Rail is itself an integral set of technologies between railroad and train. Therefore, the topic requires cross-sectoral approach, which is reflected in the competent team for cross-sectoral development of the digital railway, its users and management (Figure 1).

Development Strategy

The digitalization of the railways emphasizes the current global trend of adopting digital technologies and processes, including the deep penetration of digital technologies in the transport sector. It is also expected to take advantage of the significant experience of the European railway sector for innovative development.

Although it has the potential to be a driver of the game for the rail industry, digitalization is not an end in itself. It provides unique tools to increase the efficiency of rail transport that can stimulate the transition to a new level of industry development.

For example, the widespread use of next-generation low-pass wireless networks, such as LoRa, as well as the enormous processing capability offered by cloud-based technologies, can open the way for the development of an integrated technology platform that supports decision making for all industrial processes. (LoRa – Low power Radio technology – wireless RF technology used in WAN for M2M and IoT applications thanks to low power consumption and secure data transmission).

In an effort to maintain the achieved market share while ensuring continued sustainable development, European railways have developed their own innovative development plans for the immediate prospective period. These plans envisage the widespread use of digital technologies in all company business, including fleet and infrastructure monitoring, communications, traffic management and trains management.

At the heart of today's transition, new digital business data is based on data based on the auto-

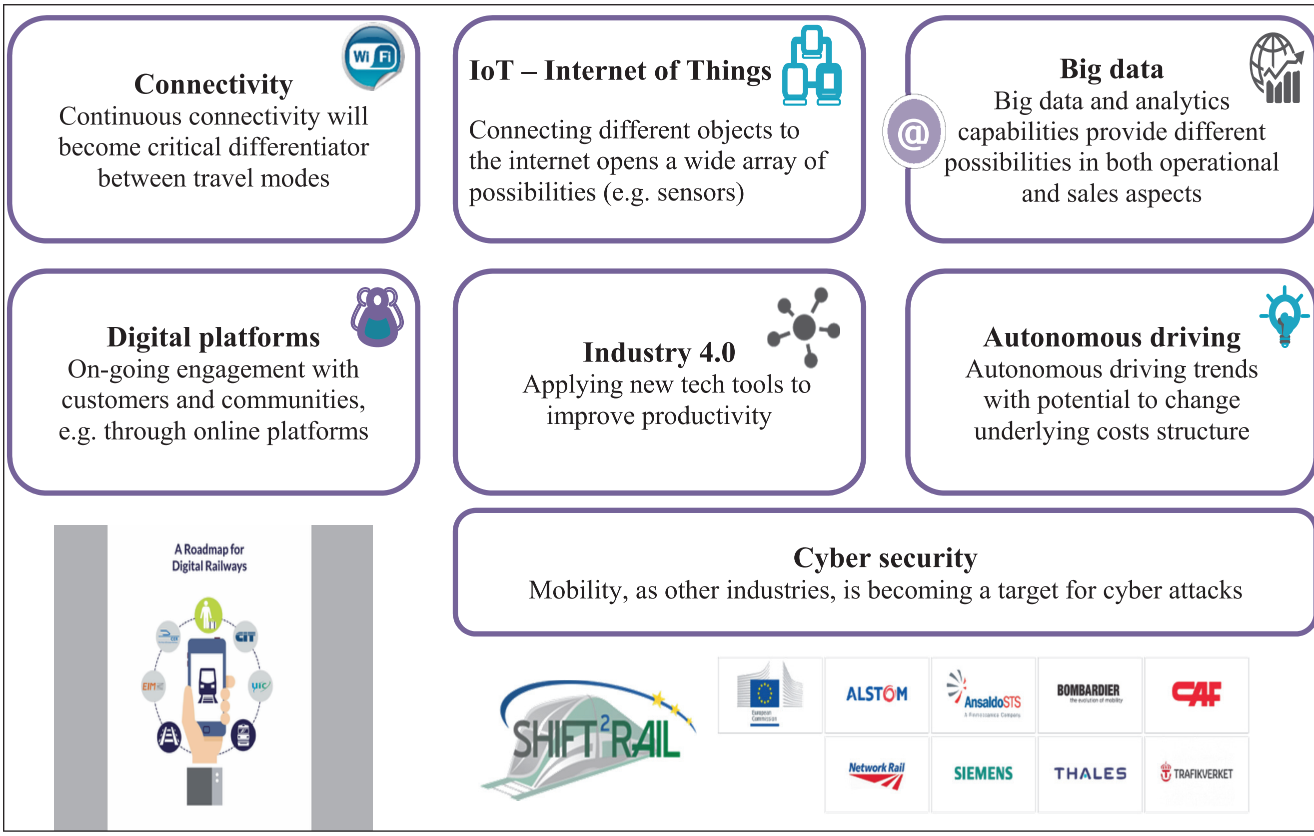

Figure 1. Today's challenges. Tomorrow's opportunities

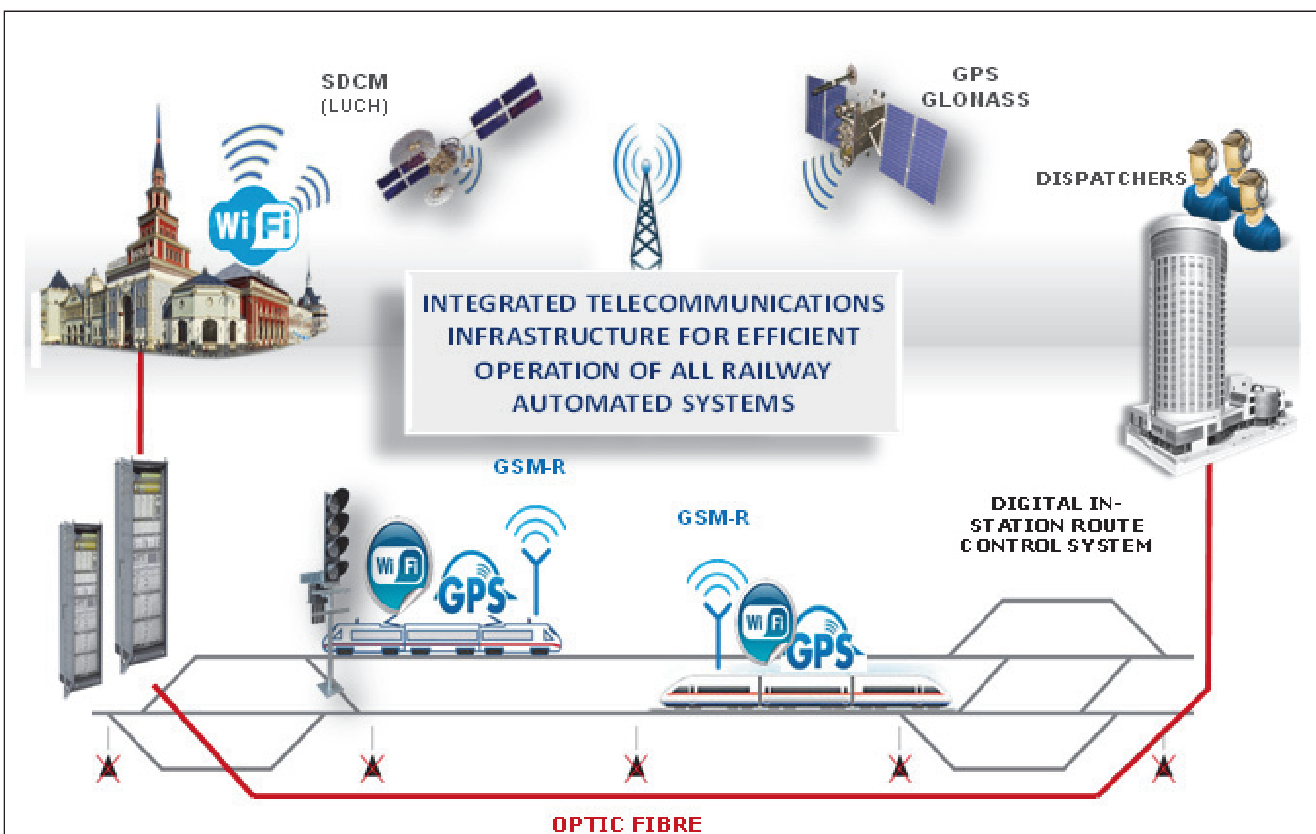

Figure 2. *Integrated Telecommunications*
SDCM System for Differential Corrections and Monitoring (component of GLONASS), Luch - family satellites

mation of data collection from specific work parameters and industrial processes.

In the rail context, this implies the development and improvement of digital or virtual images of objects and processes. Digital images help solve the whole spectrum of problems.

For example, analyzing and simulating the behavior of a digital image of a device, which is made using information collected by specialized monitoring and diagnostic sensors throughout the device's lifecycle, provides access to accurate information about vital device parameters, such as: work safety, resilience/robustness and longevity (Figure 2).

Practical Solutions

The concept of a digital railway is inevitably linked to fully automatic trains without a driver. The so-called smart locomotives and smart trains are considered to be the future of rolling stock, and many railways are actively developing this technology, along with prototypes that already pass tests on some test pieces.

In several world examples, the operation of automatically guided locomotives has been successfully tested at marshalling yards.

Here, the speed of the track is controlled via a digital radio block with continuous automatic monitoring of their location using GPS / Glonass satellite navigation with differential correction. The purpose of this project is to develop a procedure for the simultaneous control of several shunting units from one remote workstation.

Another innovative solution, developed for positioning trains, is the use of monitoring of vibration acoustic paths. In this system, train presence detection is based on an optical sensor for identifying precise coordinate positioning of trains on open lines between stations.

This technique requires the conversion of the backup fiber into an optical cable into a spatially distributed sensor, which works on the basis of determining changes in signal reflection from the cable while the train passes along the line. This is done using a measuring gauge located on the periphery with the differences between the reflecting branches that provide an accurate measurement of the position of a particular vehicle. The system permits the monitoring of the vehicle fleet within 40 km of the gauge - reflectors and locations of the central computer unit with a positioning accuracy not less than 15 m.

The techniques that work in accordance with the concept of the Industrial Internet of Things (IIoT), which is increasingly accepted throughout the rail world, have greatly applied. Today, a large number of technical and technological solutions at the IIoT base go through tests on various parts and objects of the world rail network.

Railways today are considering and testing other low-voltage wireless communication solutions. It also tests and uses a wide range of applications that use wireless sensors to collect information and realize remote transmission in the rail environment as part of the IIoT concept. Promising results of wireless sensors for automation systems for railways, such as signals, relay groups and cabinets, tracking equipment and overheating detection systems, are expected.

All information pertaining to the operation of the railway facilities collected by the distributed sensor network is transmitted to the appropriate automated control systems of the railways that are connected to a reliable corporate communications network.

A special feature of the selected IIoT concept is the deep vertical and horizontal integration of automated industrial control systems. European railways have developed RDBMS as a platform for the integration of all automated traffic management systems. The platform is complemented daily and perfected by passing through the concepts based on a multi-agent approach. This improvement relies on the principles of artificial intelligence, developed to integrate and process large amounts of data from traffic processes. This may include the current status of signaling systems, speed and weight of trains, location of locomotives, trains, cars, speed limits per line sections, as well as the technical condition of rolling stock and automation devices.

The RDBMS project assumes that the fleet acts as a sensor. It should be noted that its source is seen in the first solutions in the world based on equipping the fleet with a train protection system integrated with GPS / Glonass satellite receivers, which are able to transmit the position of the train and other data through the radio link to the traffic control center.

In addition, the latest generation of EMU solutions, such as Lastochka and Sapsan [5], are equipped with special information and measurement systems for diagnostics and monitoring, which provide complete automatic control over the state of the infrastructure during everyday tasks.

This includes LoRa, which provides guaranteed wireless communication channels in a range of 15 km in poorly populated and 5 km in densely developed urban areas. It has been proven that the LoRa-based communication network has sufficient robustness at a high level of interference and an unfavorable electromagnetic environment.

Reliable information about the state of the railway infrastructure and facilities is one of the key components of intelligent data processing and analysis systems. This also implies the development and implementation of decision support solutions at the highest level.

New Access to Diagnostics and Monitoring

New equipment for diagnostics and monitoring of accessories is installed on the existing fleet without overlapping with the existing classical equipment.

Diagnostic activities do not interfere with the traffic process, and at the same time provide high frequency traffic monitoring of high speed trains.

Diagnostics of the condition is carried out without interruption of the work of the rolling stock, the railway infrastructure and the contact line.

Full automation of all control equipment for diagnostics, measurement, processing and monitoring has been realized (does not require presence of operator).

Diagnostics makes it easier to apply a new approach to maintenance of rail infrastructure and rolling stock based on the collected data. In addition, various wireless sensors installed on a fleet, which include a wide range of digital subsystems, including acoustic sensors and technical modes, can be supplemented by fixed, integrated inspection stations. As a result, the technology not only identifies the wear or critical state of the components, units and plants, but also provides a supported forecast of equipment deterioration, as well as full information when deciding on the allocation of maintenance activities (Figure 3).

A high-quality, modern diagnostic hardware-software platform has already implemented some, but also all the following features, based on the automation of data collection and application:

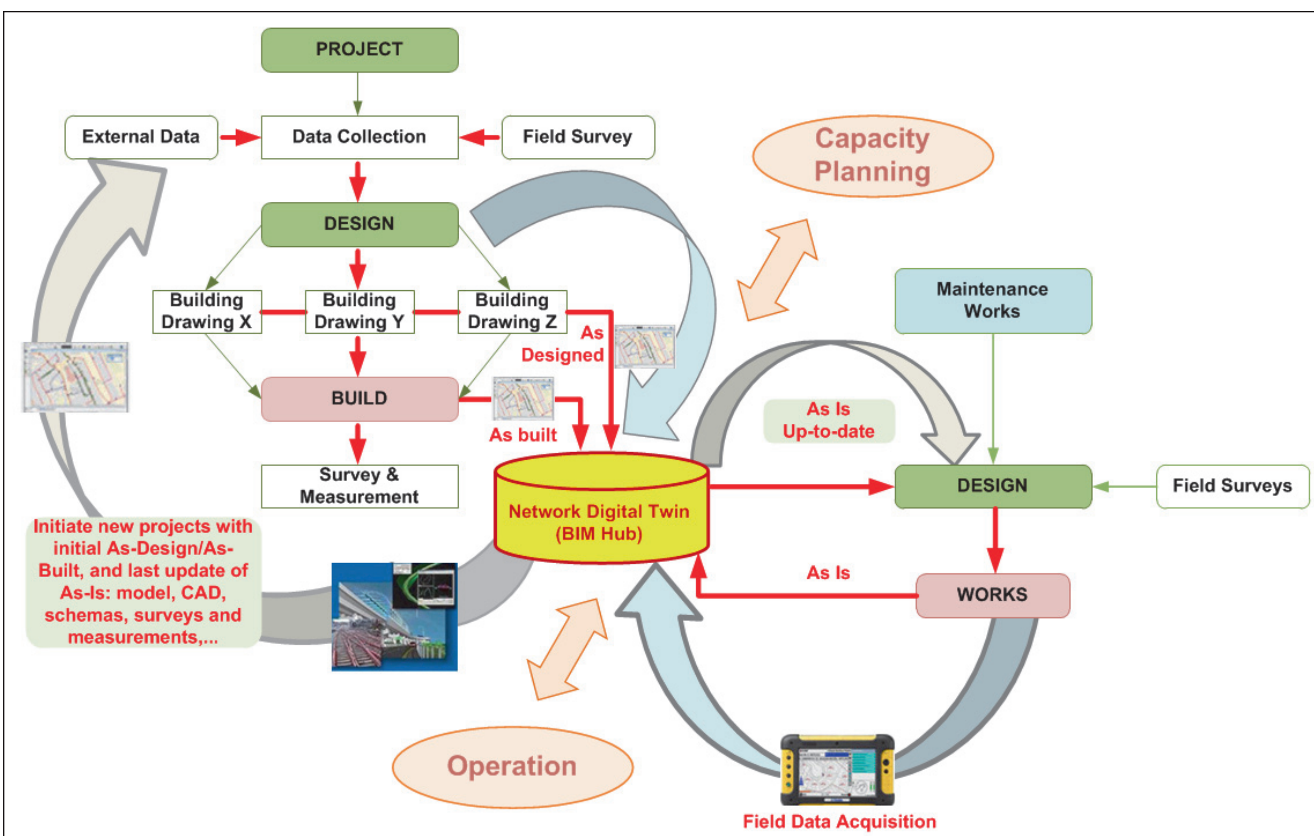

Figure 3. *UIC RailTopoModeL (RTML)*

- automation of the initial processing of statistical data on railway infrastructure and the failures of the equipment of the vehicle fleet,
- identification of quantitative values of operational reliability and safety indicators of infrastructure objects,
- quantitative assessment of infrastructure and service activities that are the subject of failure and organization of maintenance and operation of infrastructure facilities,
- monitoring, comparing and supporting the activities of associated business units based on operational reliability and safety indicators,
- assessment of compliance of real performance indicators and work safety within standard norms,
- preparation of estimated data to support recommendations for risk reduction,
- identification of vulnerable objects based on risk assessment,
- drafting work plans for the maintenance of infrastructure and rolling stock, and
- preparing investments in projects for those railway facilities that are the biggest problem.

Geographic Information Systems

One of the priorities set before digitization in the modern rail industry is the use of geographic information systems in the widespread application, automatic generation and updating of digital models of a dotted, linear or parallelogram type with a rich set of precise data.

For several years, this technology has been tested in a range of operating environments. For example, the use of digital rail models that offer precise coordination of coordinate infrastructure facilities has enabled the automation of maintenance and mapping procedures that have significantly reduced costs and improved the quality of the activities carried out. This approach, in addition, offers the possibility of assigning maintenance operations with an accuracy of the order of cm, which advanced railways encourages to introduce this technology into their network.

Further development is based on an integrated system of spatial data of railway infrastructure, which is in development phase, with a highly precise coordinate system, which is primarily intended for the design, construction, maintenance and exploitation of infrastructure.

One such solution was used in a large and extensive project of reconstruction of the Moscow Ring Railway.

The reconstruction project involves the management of mixed passenger and freight traffic. For these purposes, a complex system for train separation has been developed, which is based on an automatic rail block and uses circular streams of audio frequencies integrated with computer blocking on stations and ATP systems on trains.

This enabled the automatic separation of trains using the principle of a mobile block, and can operate in two ways: a mode of operation with light signals for organizing the operation of freight trains of a certain mass and length and a light signal without a working mode for operation at higher EMU speeds with a minimum interval of three minutes.

The system provides automatic train guidance to the specified target and automatically identifies and resolves possible conflicts by calculating and performing an alternative approach. In the event of train delay, this process attempts to compensate for lost time. The position and speed of the train are determined by using GSM-R, and the integrated positioning system based on satellite navigation devices is part of the train protection system.

Conclusion

Real-time rail traffic management will reduce disruptions, increase safety, improve reliability and enable a better response to new passenger demands.

It should be noted that in a large number of applications on the rail network traditionally used track circuits, as a basic element of railway automation and telemechanics. With them, we detect the presence of a moving structure on some part of the track and the whole of the rail.

Although still a very reliable element, its improvement is being investigated. Today, the rail power circuit serves as the primary channel for transmitting information on signal aspects and the allowed speed of the train.

Track circuits are not an ideal solution. This channel is inferior to the digital radio. Track circuits are very sensitive to interference. However, they are more reliable than radio links in terms of cyber threats. Further development of the track circuits is seen as a kind of combination of these media with the improvement of cyber security. Track circuits are already becoming digital, with digital generators and filters that provide high functionality and availability.

In any case, the concept of a multilayer security system is being promoted today in the world. It is intended that the entire railway territory is fully covered by the digital generation of the latest generation. GSM-R is slowly becoming an outdated solution with its known limitations.

We need a new broadband digital radio communication for the digital railway.

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Submitted: January 27, 2019
Accepted: April 4, 2019

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For citation

Avramović Z.Ž., Marinković D.M., Lastrić I.T., Digitalization of Railways – ICT Approach to the Development of Automation, *JITA – Journal of Information Technology and Applications Banja Luka*, PanEuropien University APEIRON, Banja Luka, Republika Srpska, Bosna i Hercegovina, JITA 9(2019) 1:17-23, (UDC: 656.2:[621.313:681.5), (DOI: 10.7251/JIT1901017A), Volume 9, Number 1, Banja Luka, june 2019 (1-48), ISSN 2232-9625 (print), ISSN 2233-0194 (online), UDC 004