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SECURITY AND PROTECTION OF INFORMATION SYSTEMS IN THE CONTEXT OF INTELLIGENT TRAIN CONTROL SYSTEMS: FUTURE FOR BULGARIAN STATE RAILWAYS

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Abstract: *The report examines the main aspects of information systems security and protection, emphasizing the need for reliable strategies and technologies for their protection. Information security encompasses measures, policies and technologies designed to protect information resources from unauthorized access, use, disclosure, disruption, modification or destruction. The main objectives are: confidentiality, integrity, availability. It examines threats to information systems, which can be classified as: internal (employees, errors, sabotage), external (hackers, malware, natural disasters), technical (hardware failures, software bugs).*

Protection methods include: updates, antivirus software, middleware, network segmentation, access control, cryptography and cryptographic tools, data protection through: symmetric and asymmetric encryption, hash functions, digital signatures, certificates, network security.

The report examines the essence of intelligent train control systems (ITCS), technological components of ITCS, international practices and examples, analyzes the current state of BDZ and NRIC, the opportunities and scenarios for the implementation of ITCS in Bulgaria. It examines the economic, environmental and social effects, obstacles and risks of implementation. The report provides strategic recommendations and an action plan.

Keywords: *security and protection of information systems, intelligent train control systems*

Bulgaria, as a member of the European Union, is obliged to adapt its transport systems to common European standards, including the European Rail Traffic Management System (ERTMS). However, the country's railway sector continues to suffer from lagging behind in terms of its technological infrastructure, low operational management efficiency and limited interoperability with the European railway system.

Intelligent Train Control Systems (ITCs) are a set of technologies and processes aimed at automating, coordinating and optimizing rail traffic. They are part of the broader concept of Intelligent Transport Systems (ITS), which encompasses both passenger and freight transport.

The goal of the IMS is to create an integrated and digitally managed railway network capable of meeting the requirements of modern society - in terms of safety, speed, punctuality, capacity and environmental sustainability.

Main functions of the IMS include: automated traffic management and train routing, centralized monitoring of operational activity, real-time forecasting and adaptation of timetables, signaling and access control to railway sections, integration of information flows between operators, infrastructure managers and passengers, predictive maintenance of rolling stock and infrastructure through IoT and Big Data.

In the European context, ERTMS is mainly associated with the European Rail Traffic Management System (ERTMS), which combines digital signalling (ETCS – European Train Control

System) and the GSM-R communication standard for trains. This creates the prerequisites for harmonizing the railway network on the continent and facilitating cross-border transport.

Intelligent management is not limited to traffic control – it also includes a complete transformation of business processes in railway operators, automation of workflows, improved communication with customers, and digitalization of maintenance and resource management.

The importance of IMS will continue to grow in the coming decades, with the integration of artificial intelligence, machine learning and cloud technologies expected to make rail transport even more flexible, predictable and cost-effective.

Intelligent train control systems consist of various technological solutions that function synergistically to achieve automation, safety and operational efficiency. The main technological components of the ITS and their role in the overall system architecture include:

1. ETCS (European Train Control System):
• Standardized system for signaling and traffic control.
• Supports different levels of automation:
o Level 1: classic relay signaling with balises,
o Level 2: continuous communication via GSM-R,
o Level 3: virtual block sections with maximum automation.
• Main component for compatibility with the European railway network.

2. GSM-R (Global System for Mobile Communications – Railway):
• A specialized telecommunications standard for railway transport.
• Allows reliable exchange of voice and digital information between trains and control centers.
• A necessary basis for ETCS Level 2 and 3.

3. Automatic Train Operation (ATO):
• A system that automates acceleration, braking and schedule compliance.
• Increases accuracy and reduces human error.
• When used in conjunction with ETCS, allows for full autonomy (GoA 4).

4. SCADA systems (Supervisory Control and Data Acquisition):
• Centralized systems for monitoring and controlling power supply, signaling, climate conditions and
safety.
• Collect and analyze real-time data from the railway infrastructure.

5. IoT sensors and predictive maintenance:
• Installed on trains and tracks for continuous monitoring of the condition of components.
• Use of artificial intelligence to predict failures.
• Optimizes maintenance costs and increases uptime.

6. Centralized Traffic Control (CTC):
• Unifies traffic management from different areas into one coordinated control center.
• Allows real-time response to emergencies.

7. Cloud platforms and Big Data Analytics:
• Centralized storage and processing of data from all systems.
• Ability to strategically plan, optimize schedules and freight flows.

8**. Passenger service platforms**:
• Mobile applications and web systems with real-time information on schedules, delays and transfers.
• Integration with electronic tickets, reservations and customer service.

Many countries around the world are already successfully implementing Intelligent Train Control Systems (ITCS) as part of their efforts to modernize, safety and sustainability of rail transport. These examples provide valuable experience that can be adapted to the needs of the Bulgarian railway system.

1. Germany – Deutsche Bahn and Digital Rail Germany. The Digital Rail Germany program envisages the complete digitalization of the railway network by introducing ETCS and ATO. Sections such as Erfurt – Leipzig are already equipped with modern signaling and fully digital control. The goal is full digitalization of the network by 2035, including centralized management and capacity optimization.

2. France – SNCF and autonomous trains. SNCF in partnership with Alstom is developing autonomous trains, with ATO up to GoA 4 (driverless). They are introducing systems for automatic acceleration and braking, real-time traffic analysis and energy efficiency. The test trains are running on real routes with digital monitoring and control.

3. UK – Digital Railway Program. Part of Network Rail, this program aims to deploy ETCS and ATO on busy lines such as Thameslink. Full integration of ATO with ETCS on existing infrastructure has been achieved – the first of its kind in Europe. It is expected to significantly increase train frequencies and reduce delays.

4. China – Autonomous high-speed trains. China is a leader in the application of IMS on trains with speeds above 300 km/h. On the Beijing – Zhangjiakou route, trains are operated with ATO and are integrated with facial recognition and predictive control systems. The systems use AI to allocate passenger flows and minimize costs.

5. Japan – JR East and IoT support. Japanese railways use IoT sensors and SCADA platforms for diagnostics and maintenance. The data is used to predict failures, optimize routes and reduce unexpected disruptions. Trains are monitored in real time via a centralized system, allowing for rapid response to incidents.

6. Switzerland – Integrated railway system and punctuality. Swiss Railways (SBB) combines traditional precision with digitalization. They use centralized management, dynamic train rerouting and passenger communication platforms. They have introduced capacity optimization tools through simulations and predictive algorithms.

7. European Union – Funding through CEF and Green Deal. The EU is funding the deployment of ERTMS and ISUV through the Connecting Europe Facility (CEF), the Green Deal and the Recovery Plan. Targeted funds are provided for development, deployment and training. Standardization of infrastructure and signaling is a strategic priority until 2030.

International experience shows that the digitalization of the railway sector is possible and brings real benefits with a clear vision, institutional coordination and investments. Bulgaria can adapt good practices to its reality through phased implementation and effective absorption of European funds.

Given the current state of the railway system and the EU's strategic goals, the implementation of intelligent train control systems (ITCS) in Bulgaria represents both a challenge and an opportunity for transformation. A phased approach, consistent with the resources, capacity and priority areas in the country, is necessary to achieve a sustainable effect.

1. Pilot projects: Implementation of ETCS and ATO on key lines such as Sofia - Plovdiv, Sofia - Varna, Plovdiv - Burgas. Use of available modern rolling stock with the possibility of integrating on-board technologies. Installation of IoT sensors on the infrastructure and trains for monitoring and predictive maintenance. Real tracking of results through KPIs - accuracy, costs, number of incidents, capacity.

2. Centralized command and digital control: Construction of a National Center for Digital Traffic Management with SCADA, CTC and Big Data. Integration between NRIC and BDZ with automated platforms for planning, monitoring and communication. Connection with the European Interoperability and Control Systems (ERTMS).

3. Adaptation of the normative and regulatory framework: Updating of technical regulations according to the European TSI (Technical Specifications for Interoperability). Creation of a legal basis for the introduction of autonomous technologies (GoA 3 and GoA 4). Facilitation of public procurement procedures for innovative projects.

4. Human capital development: Training, certification and retraining of employees from BDZ and NRIC in the field of IT, telecommunications, system integration. Creation of university programs and joint initiatives with the industry and the scientific community. Integration of cybersecurity and digital culture in the transport system.

5. Funding through EU programs and public-private partnerships. Maximizing the use of funds from: Connecting Europe Facility (CEF), Recovery and Resilience Plan (RRP), Horizon Europe and national operational programs, Promoting PPPs (public-private partnerships) through clearly defined risks, commitments and benefits.

6. Integration with multimodal transport and digital services: Connecting rail transport with urban and intercity transport through integrated tickets and timetables. Mobile application platforms

with real-time information, electronic ticketing and customer service. Creation of open data (Open Data) for logistics operators and business users.

7. Possible time scenarios

Short-term (1–3 years): pilot lines, training, adaptation of regulations.

Medium-term (3–7 years): expansion of coverage, centralized management and digitalization of operations.

Long-term (8–15 years): autonomous trains, full interoperability with the EU, national digital hub and cloud management systems.

Despite the significant benefits of implementing intelligent train management systems (ITMS), the process is accompanied by a number of challenges that may hinder its successful implementation. Recognizing and overcoming these barriers is crucial to achieving sustainable progress.

1**. Financial constraints**: The lack of sufficient own funds in BDZ and NRIC leads to dependence on European co-financing. There is competition with other strategic sectors (healthcare, energy), which limits public investment in rail transport.

2. **Insufficient administrative capacity**: The lack of prepared human resources in state institutions to manage IMS projects is a serious challenge. Frequent changes in management and long project approval cycles hinder progress.

3**. Weak coordination between institutions**: The division of responsibilities between BDZ, NRIC, the Ministry of Transport and other bodies creates bureaucratic difficulties. The lack of a unified approach and clearly defined roles slows down the implementation of complex projects.

4. **Resistance to change**: Staff in the railway sector often have many years of experience and are opposed to automation due to fear of layoffs or unfamiliar technology. A change management program is needed, including communication, training and incentives.

5. **Technological fragmentation and lack of standardization**: The existing infrastructure uses incompatible systems, which makes integration with ETCS, ATO and other ISUV modules difficult. Bulgaria is not yet fully harmonized with the EU Technical Specifications for Interoperability (TSI).

6. **Cybersecurity risks**: Digitalisation increases vulnerability to cyberattacks, sabotage and system failures. A cyber-resilient architecture is required, including protection of critical transport infrastructure.

7. **Dependence on external suppliers**: The limited domestic capacity to produce signalling and IT equipment leads to dependence on foreign technologies. This increases costs and hampers flexibility in deployment or upgrading.

8. **Public distrust**: Citizens are often skeptical of large public projects due to concerns about inefficiency, corruption or non-performance. A proactive communication campaign is needed and successful pilot projects are presented as proof of benefits. These risks can be managed through clear planning, institutional strengthening and broad public support. Smart modernisation of the railway system must happen not only through technology, but also through people, processes and trust.

9. **Strategic recommendations and action plan**: specific strategic guidelines for the implementation of Intelligent Train Management Systems (ITMS) in Bulgaria. The approach should be integrated, phased and focused on sustainable results.

Conclusion: Intelligent Train Management Systems (ITMS) are not just a technological innovation, but a strategic necessity for the modern development of railway transport in Bulgaria. At a time when Europe and the world are moving towards more sustainable, digital and interoperable transport systems, Bulgaria cannot afford to lag behind.

This analysis clearly shows that:

• The state of BDZ and NRIC requires urgent transformation – not only of rolling stock and infrastructure, but also of management models, communication and service.

• International experience proves that the integration of ITMS increases the safety, capacity, efficiency and environmental value of railways.

• Bulgaria has access to the necessary European funding, technologies and standards, but must ensure strategic leadership, institutional coordination and commitment.

The implementation of the IMS should be considered not only as a project of the Ministry of Transport or the railway operators, but as a national priority with significant effects on the economy, mobility, regional development and green transformation.

The systematic implementation of the recommended steps and scenarios will allow Bulgaria to:

- Achieve interoperability with the European railway network;
- Significantly increase the quality of passenger and freight transport;
- Realize economic benefits through efficiency and innovation;
- Strengthen public trust in BDZ and the role of railways in future mobility.

The future of railways in Bulgaria begins with digital transformation. Intelligent systems are not a luxury, but a necessary basis for a sustainable, modern and competitive transport system. It is time to act.

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