Intelligent Rail Transport Management Systems - Methodological Essence, Goals and Tasks

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Abstract. **The use of intelligent systems for the management of railway transport is a current issue related to a number of innovative methods of carrying out freight and passenger transport, traffic management and efficient use of the infrastructure. These systems allow users to be better informed and use them more safely, more coordinated and "smarter". From a methodological point of view, the requirements for these systems are growing, and the technical solutions are developing according to the trends for the development and modernization of the information technologies themselves. In this article, a generalized methodological analysis is made for the requirements, goals and tasks of these systems. The experience of the implemented intelligent systems that are used to manage railway transport is reported, as well as the types of information services that are provided for passengers and cargo.**

Keywords: Artificial Intelligence in Railway Transport, Digital management it Railway Transport, Intelligent transportation system, Railway safety,

I. INTRODUCTION

Intelligent transportation system, as a new technology and control system, is a hot topic and challenge in traffic research. The application of intelligent transportation system, in addition to road traffic, water transportation, aviation, in particular, also plays a huge role in railway transportation with "high security, high efficiency, high quality of service". This is the Rail Intelligent Transport System (RTIS). [1]

Europe faces major challenges when it comes to formulating its transportation policy. Information and communication technologies (ICT) are considered a key tool to create the intelligent transportation systems (ITS) that Europe needs. In freight transportation, ICT is seen as playing a crucial role in providing efficiency in freight transportation operation and in integrating it within the overall ITS that are now being put in place in Europe. The issues and priorities for freight transportation integration with the European ITS are presented, with concentration (as one such priority) on the issue of linking freight transportation management systems with the advanced Traffic-management systems of the European ITS. Also covered are the results so far of the thematic network THEMIS, which concentrates on the relation between freight transportation and ITS. A thematic network is a special type of research project, financed by the European Union's Directorate General of Transport and Energy in order to review and synthesize the results of research in a specific field, in this case freight transportation. The efforts made at the European level toward the formulation of a common, ITS-based freight transportation systems architecture are also reviewed. In this respect, there is a report on work done within project THEMIS. [2] [3] The EU transport system and infrastructure will be made fit to support new sustainable, compatible, secure and inter-operable mobility services that can reduce mortality, congestion and pollution. [4]

II. MATERIALS AND METHODS

Intelligent Transport Systems (ITS) in railways represent a transformative approach to modernizing and optimizing railway transportation. These systems leverage advanced technologies to enhance efficiency, safety, and overall management of railway transport. The integration of ITS in railways involves a holistic approach, encompassing various key aspects of the transportation ecosystem.

1. Digital Train Control Systems: [5]

- Automated systems for train control to manage train movements efficiently,

- Signalling systems for real-time communication between trains and control centres,

- Traffic management to optimize train movements and improve safety.

2. Communication Systems - High-speed data communication for real-time monitoring, control, and communication between trains and control centres.

3. Digital Management system of railway freight transportation based on the concept of Industry 4.0. Improving the efficiency of freight wagons monitoring system by using GPS and other sensors with geolocation technology integrated into carriage, they will alert about condition of the freight in real time. Such sensor will be able to integrate to the IoT system through a specialized Internet platform that also supports mobile version program. [6]

4. Digital Passenger Information Systems:

- Real-time information systems for passengers, providing updates on train schedules, delays, and other relevant details.

- Integrated management systems to streamline passenger services, including ticketing and journey planning.

5. Digital Ticketing and Payment Systems - Implementing smart ticketing and payment solutions for a seamless passenger experience. ITS technologies and services for the collection of fees in the field of transport have been developed in the last 20 years starting with toll collection systems, and more recently the pricing of transport, according to certain criteria (e.g. emissions). A separate section of this area is the "smart ticketing" systems i.e. ITS enabled ways to pay the tickets in public transport or other transport services.

There is a long number of policy decisions, standardization and legislative steps that create the current landscape in this area. Electronic Fee Collection (EFC) systems offer the possibility of "smart" charging for the use of transport infrastructure (mainly roads) following the pricing policies established in the different EU Directives as mentioned above. This is also called "smart pricing" as opposed to smart ticketing which refers to the collection of fares in a public transport system. According to the stakeholders' hearings, held within the STTP exercise, smart pricing will be a market where the infrastructure managers, together with the vehicles industry, and the ITS providers, will co-operate in order to produce a (road or other mode) service and provide it at a certain price to the "consumers" with one given technology or with harmonised technologies.

6. Predictive Maintenance - Using sensors, Smart devices, IoT Systems, and data analytics to predict and prevent equipment failures, reducing downtime and maintenance costs. Implementation of proactive maintenance strategies to minimize downtime and improve overall system reliability.

7. Safety and Security Systems - Deploying surveillance, access control, and emergency response systems to enhance the safety and security of railway operations. Integration of intelligent security solutions to safeguard passengers, staff and railway infrastructure stations railway.

Different multimodal transport systems - Railway, subway, airplane, and other have significant an interest of utilization of wireless communications for critical and noncritical services to improve performance, reliability, and passengers experience. [7]

8. Energy Management and Grid Optimization - Optimizing energy consumption through smart grid technologies, energy-efficient train operations, and regenerative braking. Implementation of energy-saving measures such as regenerative braking and optimizing train operations for reduced environmental impact.

Integrating these intelligent systems can lead to a more efficient, reliable, and safer railway infrastructure. It's an ongoing area of development within the broader field of smart transportation.

The introduction of ITS in railways reflects a commitment to creating a more intelligent, interconnected, and sustainable transportation system. By embracing cutting-edge technologies, railways aim to provide safer, more reliable, and convenient services while optimizing resource utilization and minimizing environmental impact.

Artificial Intelligence (AI) is becoming pervasive in most engineering domains, and railway transport is no exception. However, due to the plethora of different new terms and meanings associated with them, there is a risk that railway practitioners, as several other categories, will get lost in those ambiguities and fuzzy boundaries, and hence fail to catch the real opportunities and potential of machine learning, artificial vision, and big data analytics, just to name a few of the most promising approaches connected to AI. The scope of this paper is to introduce the basic concepts and possible applications of AI to railway academics and practitioners. To that aim, this paper presents a structured taxonomy to guide researchers and practitioners to understand AI techniques, research fields, disciplines, and applications, both in general terms and in close connection with railway applications such as autonomous driving, maintenance, and traffic management. [8] The important aspects of ethics and explain ability of AI in railways are also introduced. The connection between AI concepts and railway subdomains has been supported by relevant research addressing existing and planned applications in order to provide some pointers to promising directions. [9]
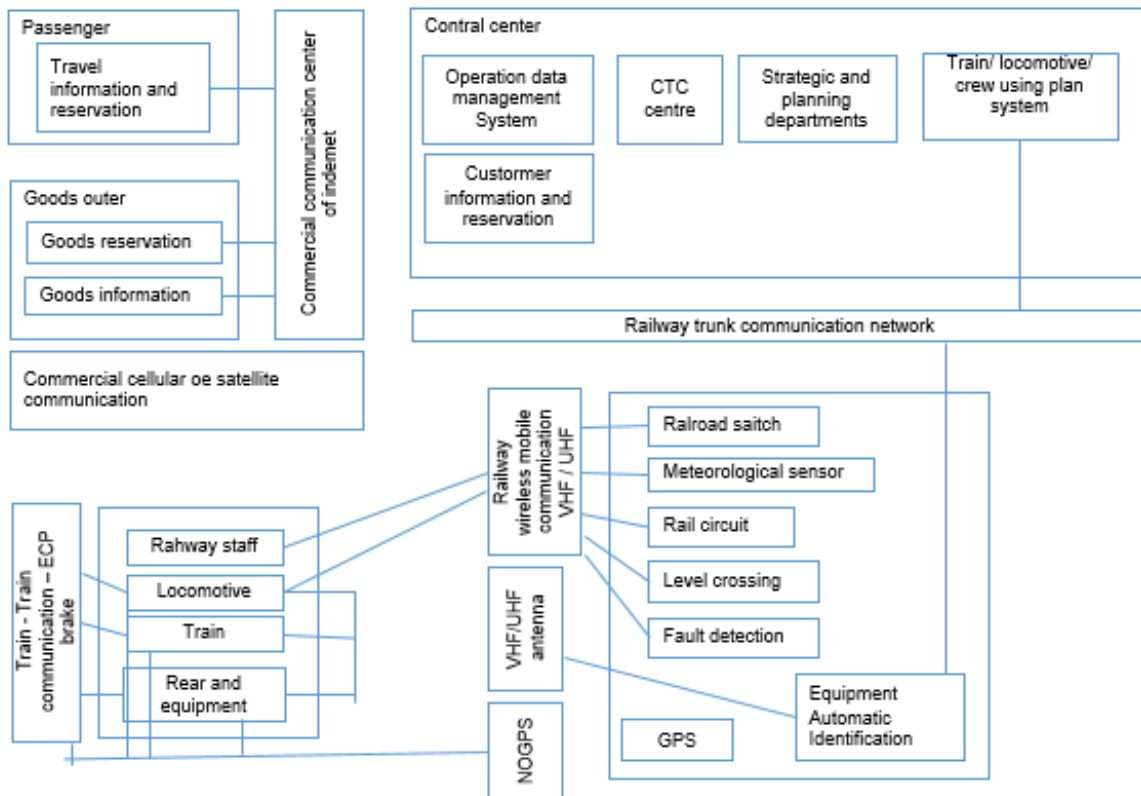
Fig. 1. Intelligent Transport Systems

Implementing Intelligent Transport Systems (ITS) in railways comes with various challenges, reflecting the complexities of integrating advanced technologies into existing transportation infrastructures. Some key challenges include:

1. Interoperability: Achieving seamless integration and interoperability among different ITS components, as various systems may come from different vendors or have different standards. [10]

2. Legacy Infrastructure: Adapting ITS to existing railway infrastructures, which may have older technologies and limited compatibility with modern systems, poses a significant challenge. [11]

3. Cybersecurity Concerns: As ITS involves extensive use of digital technologies and communication networks, ensuring robust cybersecurity measures is crucial to protect against potential cyber threats and attacks.

4. Cost Implications: Implementing ITS requires significant financial investments for technology adoption, training, and infrastructure upgrades. Balancing these costs with the potential benefits can be challenging.

5. Regulatory Compliance: Adhering to and navigating through diverse regulatory frameworks and standards, both at national and international levels, can be complex and time-consuming.

6. Data Management: Managing and analysing vast amounts of data generated by ITS components, including data from sensors and communication systems, poses challenges in terms of storage, processing, and ensuring data privacy.

7. User Acceptance and Training: Ensuring that railway staff and passengers adapt to the new technologies seamlessly requires effective training programs and addressing potential resistance to change.

8. Maintenance and Reliability: Maintaining the reliability of ITS components and ensuring timely updates and repairs is crucial to prevent disruptions in railway operations.

9. Scalability: Designing ITS solutions that are scalable to accommodate future growth in railway traffic and technology advancements without requiring significant overhauls.

10. Public Perception: Overcoming potential concerns and scepticism from the public regarding privacy issues, safety, and the overall impact of ITS on their daily commute.

Addressing challenges connected with developing and introduction of ITS requires a collaborative effort involving railway authorities, technology providers, policymakers, and other stakeholders. It also emphasizes the importance of careful planning, continuous monitoring, and a phased approach to the implementation of Intelligent Transport Systems in railways.

Implementing Intelligent Transport Systems (ITS) in railways involves a systematic methodology to ensure successful integration and optimal functionality. Here's a broad overview of the methodology:

1. Needs Assessment:

- Identify specific challenges and requirements within the existing railway system.

- Conduct a thorough analysis of operational inefficiencies, safety concerns, and potential areas for improvement.

2. Define Objectives:

- Clearly outline the goals and objectives of implementing ITS in railways.

- Prioritize objectives based on their impact on safety, efficiency, and overall system performance.

3. Stakeholder Involvement:

- Engage key stakeholders, including railway authorities, operators, technology vendors, and regulatory bodies.

- Gather insights and feedback to ensure a comprehensive understanding of the system's needs.

4. System Architecture Design:

- Develop a detailed system architecture that addresses the identified challenges and meets the defined objectives.
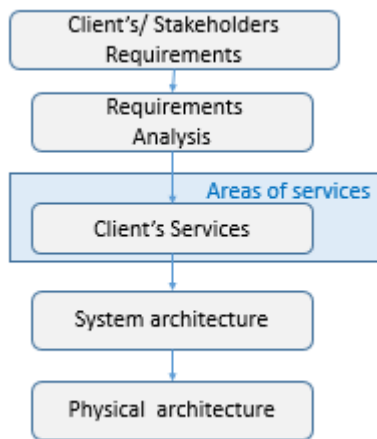

Fig. 2.   System Architecture Design

- Consider interoperability, scalability, and compatibility with existing infrastructure.

5. Technology Selection:

Evaluate and select appropriate technologies for different ITS components, such as train control systems, communication networks, and passenger information systems.

- Consider industry standards and compatibility to ensure a cohesive and integrated system.

6. Pilot Projects:

- Implement small-scale pilot projects to test the chosen technologies and assess their feasibility and effectiveness in a real-world environment.

- Gather feedback from pilot projects to make necessary adjustments before full-scale implementation.

7. Regulatory Compliance:

- Ensure compliance with relevant regulatory frameworks and standards governing railway operations and technology use.

- Collaborate with regulatory authorities to address any concerns and obtain necessary approvals.

8. Data Management Plan:

- Develop a robust plan for data collection, storage, and analysis.

- Implement measures to ensure data privacy, security, and effective utilization for decision-making.

9. Training Programs:

- Design comprehensive training programs for railway staff involved in operating and maintaining the ITS.

- Educate staff on the benefits of the new system and provide ongoing support.

10. Implementation and Integration:

- Execute the full-scale implementation of ITS components in a phased manner to minimize disruptions to railway operations.

- Ensure seamless integration with existing infrastructure and systems.

11. Monitoring and Optimization:

- Implement continuous monitoring systems to track the performance of ITS components.

- Regularly assess the system's effectiveness and make adjustments or upgrades as needed.

12. Public Awareness:

- Communicate changes to the public through effective awareness campaigns.

- Address concerns and highlight the benefits of ITS for passengers.

By following a structured methodology, the integration of Intelligent Transport Systems in railways can be executed efficiently, ensuring improved safety, efficiency, and overall performance of the railway network.

III. RESULTS AND DISCUSSION,

Intelligent Transport Systems (ITS) are implemented in railways for several compelling reasons, aiming to enhance the overall efficiency, safety, and effectiveness of railway transportation. Here are key reasons why ITS is crucial in the railway sector:

1. Improved Safety:

- ITS introduces advanced signalling and train control systems, reducing the risk of accidents and collisions.

- Real-time monitoring and automated safety protocols contribute to a safer railway environment.

2. Enhanced Operational Efficiency:

- Automated train control and traffic management systems optimize train movements, reducing delays and enhancing overall operational efficiency.

- Efficient utilization of infrastructure and resources leads to improved capacity and reduced congestion.

3. Real-time Information for Passengers:

- Passenger information systems provide real-time updates on train schedules, delays, and other relevant information, improving the overall passenger experience.

- ITS enables better communication between railway operators and passengers.

4. Predictive Maintenance:

- ITS incorporates predictive maintenance through sensor data and analytics, helping anticipate equipment failures before they occur.

- This proactive approach minimizes downtime and enhances the reliability of railway systems.

5. Energy Efficiency:

- Energy management systems within ITS optimize train operations for energy efficiency.

Energy shortage is one of the major concerns in today's world. As a consumer of electrical energy, the electric railway system (ERS), due to trains, stations, and commercial users, intakes an enormous amount of electricity. Increasing greenhouse gases (GHG) and CO2 emissions, in addition, have drawn the regard of world leaders as among the most dangerous threats at present; based on research in this field, the transportation sector contributes significantly to this pollution. Railway Energy Management Systems (REMS) are a modern green solution that not only tackle these problems but also, by implementing REMS, electricity can be sold to the grid market. Researchers have been trying to reduce the daily operational costs of smart railway stations, mitigating power quality issues, considering the traction uncertainties and stochastic behaviour of Renewable Energy Resources (RERs) and Energy Storage Systems (ESSs), which has a significant impact on total operational cost. In this context, the first main objective of this article is to take a comprehensive review of the literature on REMS and examine closely all the works that have been carried out in this area, and also the REMS architecture and configurations are clarified as well. The secondary objective of this article is to analyse both traditional and modern methods utilized in REMS and conduct a thorough comparison of them. In order to provide a comprehensive analysis in this field, over 120 publications have been compiled, listed, and categorized. The study highlights the potential of leveraging RERs for cost reduction and sustainability. Evaluating factors including speed, simplicity, efficiency, accuracy, and ability to handle stochastic behaviour and constraints, the strengths and limitations of each optimization method are elucidated. [12]

- Implementing smart technologies, such as regenerative braking, contributes to a more sustainable and environmentally friendly railway system.

6. Reduction in Congestion and Delays:

- Advanced traffic management systems enable better coordination, reducing congestion and minimizing delays.

- Efficient scheduling and real-time adjustments enhance the overall flow of trains on the railway network.

7. Improved Asset Management:

- ITS facilitates better asset management by tracking and monitoring the condition of railway infrastructure and equipment.

- This leads to more informed decision-making regarding maintenance and upgrades.

8. Adaptability to Changing Conditions:

- ITS allows for dynamic adjustments to changing conditions, such as weather, emergencies, or unexpected events.

- Real-time data and communication systems enable agile responses to unforeseen circumstances.

9. Data-Driven Decision-Making:

- The collection, aggregation, store and analysis of data generated by ITS components support data-driven decision-making for railway operations.

- This leads to more informed strategies for system optimization and improvement.

10. Integration with Other Transportation Modes:

- ITS facilitates interoperability and integration with other transportation modes, promoting seamless connectivity between railways and other forms of transport.

The main application areas of ITS in the freight transport and logistics domain are the following:

- Development and implementation of the next generation e-freight transport environment known simply as "e-freight" (inducing individual cargo item intelligence and providing interaction with the "item" throughout the transport chain);

- Freight Transport Management applications (dealing with the management of the transport operation from order capture to payment and invoice control);

- Fleet management applications with the objective of optimising the utilisation and scheduling of a fleet of freight vehicles (or wagons, or vessels);

- Management of special categories of freight such as Dangerous goods

- Terminal management including access control, loading bay and parking zone management, etc. [13]

11. Compliance with Modern Standards:

- Implementing ITS helps railways comply with modern standards and technological advancements in the transportation sector.

- This ensures that railway systems stay competitive and aligned with industry best practices.

In summary, the adoption of Intelligent Transport Systems in railways is driven by the desire to create a safer, more efficient, and technologically advanced transportation network that benefits both operators and passengers.

In this article we have used different libraries of information related with the problem of Intelligent railway transport system and conclude that the transportation systems are already more automated, vehicles have to increase capabilities of the communications and to be equipped with huge wireless communications services, sensors and controllers. Railway communications have to provide various high data rate applications for valuable passengers and for train service. [7] These business applications need to be applicable for five rail scenarios:

- Train-to-infrastructure - video and other information in real time

- Interwagon - wireless network between wagons

- Intrawagon - links between user equipment and access points of a wagon

- Inside station - links between access points and user equipment

- Infrastructure-to-infrastructure - video and other information in real time transmitting among various infrastructures.

IV. CONCLUSIONS,

Intelligent railway transport system is important part for improving transport system – modal transport, trans country, passengers and freights, containerization. ITS has huge energy impact in the transport. ITS support quality, speed, accuracy.

V. ACKNOWLEDGMENTS

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