1 Introduction

At present, rail transport obtains increasing importance in the national economy. It is about the security and facilitates the movement of more goods over longer distances at relatively low costs, that the transport of other modes of transport would be too costly and inefficient. Rail transport therefore plays an important role in economic and regional development. Rail transit systems offer opportunities for travelers to avoid traffic congestion in large urban areas (Anspacher et al, 2005). The success factors in the transport sector can be speed, capacity, level of safety and service quality.

The development of artificial intelligence, information and communication technologies allow for the interconnection and integration of these advanced technologies into the current state of rail transport in order to create a new generation of rail transport (Jia & Li, 2005). The application of intelligent transport systems in terms of rail transport to fully exploit its potential in all its areas. In this case it is able to speak of railway intelligent transportation system (RITS).

2 Intelligent transportation system

From a wide spectrum of opinion theorists and practitioners can be chosen the most accurate definition of intelligent transportation system. Their overview is given in Figure 1.
### Fig. 1 Definitions of intelligent transportation system

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghosh &amp; Lee (2010)</td>
<td>ITS is an evolving scientific and engineering discipline whose primary goal is to minimize the travel time of all travelers and merchandise while ensuring safety, through fair distribution of available resources, especially under the scenario of increasing travel speeds, a significantly large number of travelers, and a high demand for precise and timely information by travelers.</td>
</tr>
<tr>
<td>Ghosh &amp; Lee (2000)</td>
<td>ITS encompasses all of the advances in transportation and calls for the design of innovative and creative approaches to the transportation needs, utilizing the fundamental principles.</td>
</tr>
<tr>
<td>Ambak et al. (2009)</td>
<td>The term ITS refer to integrated applications, employing combinations of information, communications, computing, sensor and control technologies, which aim to improve transport safety and mobility and reduce vehicle emissions.</td>
</tr>
<tr>
<td>Seguí Pons (2003)</td>
<td>The ITS encompass a combination of transportation information, communication and technologies in vehicles and infrastructures to make them more accessible.</td>
</tr>
<tr>
<td>Křivda et al. (2005)</td>
<td>ITS is information and telecommunications support to the transport process.</td>
</tr>
<tr>
<td>Olivková et al. (2008)</td>
<td>ITS are transport intelligent services, including information and communication technologies in transport engineering in support of other related disciplines (e.g. economics, the theory of transport systems engineering, etc.) so for the infrastructure is increased safety, comfort, transportation, transportation performances and efficiency of transport.</td>
</tr>
<tr>
<td>Shladover (2002)</td>
<td>ITS is the application of information technology to improve transportation system operations.</td>
</tr>
<tr>
<td>Sussman (2002)</td>
<td>Intelligent transportation systems (ITS) apply technologies in communications, control, electronics, and computer hardware and software to improve surface transportation system performance.</td>
</tr>
</tbody>
</table>

Summarizing all considered explanations of it can be concluded that intelligent transportation system:
- must bring about a seamless and natural integration of the different modes of transportation, including vehicular traffic, trains, cargo air transport, passenger
air transport, marine ferries, and others through asynchronous distributed control and coordination algorithms, subject to social norms, policies, and guidelines (Ghosh & Lee, 2010).

- requires efficient accurate linear reference systems able to represent the elements involved in a transport network (Senguí Pons & Ruiz Pérez, 2003).
- has significant potential to enhance traffic safety (Ambak et al., 2009),
- represents an effort to use the capabilities of advanced technologies to improve transportation on many levels—to reduce congestion, enhance safety, reduce the environmental impacts of transportation systems, enhance energy performance, and increase productivity (Sussman, 2002).
- comprises two types of components: intelligent vehicles and intelligent infrastructure (Lemer, 2002).

## 3 Railway intelligent transportation system (RITS)

Railway Intelligent Transportation System (RITS) is railway transportation system of new generation, which is characterized by widespread usage of intelligent technologies, such as modern communication, modern information processing, and intelligent automation technologies (Li et al., 2005). Its essential characteristics are integrated with intelligent attributes, openness of architecture/structure, distribution of system structure, etc.

The issue of RITS in terms of Chinese railways worked out in detail in their research work the authors Jia & Li (2005), Li et al. (2003) and Xu et al. (2005). They were engaged in defining the architecture of RITS, which involves interaction between the parties. Its mission is to provide clear and simple description in understandable form. Architecture RITS contains several dimensions, namely:

- **System architecture**, which is a conceptual description of the application of RITS,
- **Functional architecture** that defines what services will provide RITS,
- **The organizational architecture** that describes how the different data redistributing and processing,
- **The physical architecture**, which defines the functions of each subsystem,
- **Reference architecture** that addresses the harmonization of international expansion and RITS.

*The system architecture of RITS*

It formally defines the relations between all the key elements - the individual elements and objects together with their subsystems and components provide rules for how they should work. It also provides a chart which defines the interface specifications and overall system design (Schlosser, 2001, p. 70). RITS system
architecture must include modern technology (Hi-Tech), enabling efficient use of equipment, space, time and human resources to ensure the already mentioned above four key factors (speed, capacity, safety and quality of service).

**Functional (Service) architecture of RITS**

The functional architecture leads to redistribution and prioritization of services provided to users of the transport process. The users may include railway operators, passengers, consigner, information service providers, operators of other transportation modes, etc..

Due to the three main objectives (higher efficiency, safety and quality of services) comprises a functional architecture RITS 7 fields and 21 sub-fields (more in Jia & Li, 2005):

1. Intelligent User Navigation System (IUNS)
2. Railway E-business System (RES)
3. Inter-Modal Transportation System (IMTS)
4. Intelligent Emergency rescue & Safety supervision System (IESS)
5. Intelligent Railway Resource Management System (IRRMS)
6. Intelligent railway Operation Management System (IOMS)
7. Intelligent train control & dispatching system (ITCDS)

**The logical architecture of RITS**

It is a model describing the nature of the system based on the information management process and their functions in terms of internal organization. It provides functions that RITS must be made to meet user requirements and information flows between these functions. The logical architecture is described by DFD and a simplified top-level logical architecture of RITS is presented as Fig. 2.

**The physical architecture of RITS**

It allocates functions defined in the logical architecture to physical resources - subsystems based on functional capacity of processing situation on the ground, where they operate. There are also reflected in the institutional elements of accountability. This is a description of the physical configuration of the physical links, communication tools and software modules with the task of achieving their function and trouble-free performance (Schlosser, 2001, p. 76). Physical architecture for China national RITS includes 6 systems: user system, Service system, center system, trackside system, train system and station system (Fig. 3) (Jia & Li, 2005, p. 1430).
4 Implementation of RITS

The implementation of RITS is a difficult process mainly based on the planning of concepts of strategic solutions, implementation, projection solutions and operation. Schlosser (2001) divides the implementation into three basic stages, namely:

1. ITS concept - strategic solution
2. Implementation of ITS
3. Projection solution ITS

Fig. 2 The top-level logical architecture of RITS

Source: Jia & Li, 2005, p. 1430
The first stage is necessary to set a strategic goal RITS and its object the provision of traffic management services. Schlosser (2001) advised the following steps:

1. **Identify investors**: traffic engineers have to ensure participation of all major organizations involved in the construction of RITS.

2. **Develop an inventory of existing ITS applications**: traffic engineers have to base on current situations, which RITS are already in operation in the implementation phase, or planning

3. **Analysis of the transport requirements**: traffic engineers detailed analyse the transport requirements based on the results of analyses and discussions with investors and opinions critical offices. The result of this phase is the mapping of quality problems and the state of user functionality provided by RITS,

4. **To determine a possible time implementation of ITS in the short and long term**: traffic engineers need to demonstrate the technological, financial and organizational risks, account the effects of possible disruption in implementation of RITS and weaknesses,

Source: Jia & Li, 2005, p. 1431
5. Define requirements for the architecture of RITS: traffic engineers to be based on activities involving users and the interaction, which involves a separate system and organization

6. Documentation: traffic engineers must develop a detailed design documentation RITS in the form of summaries and priorities for implementation of RITS.

The second stage is the actual implementation, which is influenced by several factors. RITS implementation plan must therefore include well-defined roles and responsibilities of various organizations, and specific recommendations on how investors can hold each other.

An essential step in the implementation is the projection solution of the RITS. Development of the RITS is very difficult and at present there is no fixed curriculum, as traffic engineers should proceed because each application of ITS is specific. Although it is possible to recommend the following outline of the project RITS:

1. History: The motivation of action and special circumstances,
2. Objectives: The specific subject and ways to address the process may change over time,
3. Technical description of the elements: the system and level of detail
4. Non-technical description of the elements: the institutional level and in terms of road users,
5. Experience: positive and negative, which include:
   - Handling the administrative and financial steps (acceptance costs and budgetary constraints, the technical solution, state legislation, public involvement, organizational and institutional solutions)
   - Gradual steps of the solution (formation of a consortium of public, private and academic sectors, requires a change in legislation, ITS strategic plan for state and regional level, research and development, operational tests in real environment, early implementation of IDS, IDS full extension, the impact of ITS)
   - Implementation of applications in practice.

The structure and content of the curriculum project RITS will depend on a large number of negotiations and creative work of the working groups. Gradually, in the forthcoming document will be reflected the benefits and requirements for forming RITS.
5 Discussion

Railway intelligent transportation system (RITS) is a rail transport system of a new generation that integrates smart technology, people and information (information flow). We can talk about the three basic dimensions (Fig. 4):

1. Technological dimension
2. Information dimension,
3. Human dimension.

Fig. 4 Dimensions of RITS

Human dimension

The human element is a specific part of the RITS, where holders are railway operators, passengers, consigner, information service providers, operators of other transportation modes, etc. Railway operators record and analyse all traffic information and other relevant data on a permanent basis. When an event or an extraordinary situation arises, they evaluate the need for intervention, launch the appropriate measures, and monitor the implementation of the measures prescribed. Holders of management functions should, in particular to develop new plans and traffic management to ensure sustainable development of existing plans. Passengers have valuable ideas for improving the transport processes. They are very sensitive to any changes and service quality. The human element plays a very important role in RITS.

Technological dimension

Information technology (IT) provides the means to store, manipulate, and disseminate massive amounts of data. The integration of IT at all levels of the transportation system creates the intelligence in intelligent transportation systems. But...
this integration is a long and difficult process of searching for and exploiting opportunities in the interconnected operations, planning, and funding of today’s transportation systems. (Varaiya, 2002).

ITS technology can continuously collect data on current conditions, continuously predict near-term behaviour and continuously act to optimise safety and throughput (Kabashkin, 2007). Modal facilities can be monitored for incidents and predicted impacts on related infrastructure. The system can use real-time simulation combined with adaptive and predictive real-time modelling technology to foresee future conditions and adjust to operate with much greater efficiency, safety and performance reliability.

Technological orientation is an important dimension of RITS. For successful application of ITS must be created an infrastructure consisting of actuators (lights, variable traffic signs, billboards...), sensors (detectors, video detection systems, environmental monitoring...), communication infrastructure / environment (RDS radio TMC-, short-range DSRC multimedia transmissions, GSM transmission, digital radio transmission networks...) and information technology (IT physical layer, transport telematics software resources...) (Kachman, 2007). The communication infrastructure is the backbone of RITS. Intelligent transport systems make extensive use of a seamless communications infrastructure, including satellite and land-based communications; fixed and mobile services; radio broadcasting; and 2-way communications for data, voice, image and video services.

Information dimension

For effective functioning of RITS is essential to ensure good quality information. It is possible to achieve flawless functionality of the system. RITS collects information, processes them and sends them back to provide a service. The Important role plays information chain, which involves the acquisition and data collection, data processing, communication - the transfer, redistribute of the information and use of information.

On the based of ITS literature analysis (Hartenstein & Laberteaux (2010); Bishop (2005); Mikulski (2011); Williams (2008); Kumamoto (2007); Ghosh &Lee (2000); Sussman (2000); Ozbay &Kachroo (1999); Schlosser (2001); Přibyl &Svítek (2001); Olivková et al. (2008)) were identified five key elements of RITS, which affect its efficient functioning. This may enroll in the shape of the functions of five variables that affect the implementation and operation of RITS:
\[ R_{\text{ITS}} = \{I_{\text{CT}}, P_M, M, T_R, P\} \] (1)

where

- \( R_{\text{ITS}} \) – Railway intelligent transport system,
- \( I_{\text{CT}} \) – Information and communications technologies,
- \( P_M \) – Process management,
- \( M \) – Management,
- \( T_R \) – Technical resources,
- \( P \) – People.

It is important that all the links and relationships between variables were conducted with a focus on quality assurance services, higher speed and higher level of security. In light of that RITS function is seen as an integrated transport system utilizing resources and organizational support for process management, backed by technical means, especially intelligent technology. The output of the function is created value by improving the safety, speed and quality of services.

The first important element influencing the RITS as information and communication technologies, including intelligent technologies used in the transport process. The continuity of information flow will depend on the utilization rate. The second element is the process management in terms of use and implementation of control strategies and algorithms. This element identifies all the processes related to RITS. Knowledge and process description is the basis of continuous improvement processes.

The third element is the management of the importance of providing organizational support. This is the choice of a suitable organizational structure, traffic management, destination decision-making powers and responsibilities of individual organizations, but also the determination of standards. This factor contributes significantly to the formation of every RITS.

The fourth element is the technical resources. This is the physical equipment necessary for the operation of RITS. The last element are the people. This is a very important element of which will depend on the quality of service, setting and the development itself RITS.

6 Conclusion

The architecture RITS for conditions of Chinese rail system may serve as an example of successful transformation of the traditional rail transport to the next
generation. Such change, however, in the Slovak Republic and the government needs the support of the Ministry of Transport, Construction and Regional Development. Modernisation of railways and application of intelligent transport systems in terms of rail transport may not only represent the development of this mode, but also increase the competitiveness of railway undertakings in the market.

The formation of ITS is necessary based on the principle: ITS systems can not be bought, but can be purposefully built (Pribyl & Svitek, 2001). Intelligent transport systems are widely used in logistics. Increasingly are the requirements for intelligent logistics and construction of new modern logistic centres. The most common techniques for logistics include Global Positioning System (GPS), Geographic Information Systems (GIS) and advanced information systems (Tseng et al., 2005). In real time, can be watched the movement of vehicles and containers, enabling more effective planning (for more Cempírek et al. (2010); Šulgan et al. (2008)).

This publication is the result of the project implementation:

Centre of excellence for systems and services of intelligent transport, ITMS 26220120028 supported by the Research & Development Operational Programme funded by the ERDF.

"Podporujeme výskumné aktivity na Slovensku/Projekt je spolufinancovaný zo zdrojov EÚ"

References


Resume

At present it is often said about the new generation of rail transport, which will allow greater speed and capacity, a higher degree of safety and service quality. The paper deals with the application of intelligent transport systems in terms of rail transport, particularly railway intelligent transportation system (RITS). This paper describes the design, architecture and implementation of this system.

Key words

railway intelligent transportation system, intelligent transportation system, elements, transport, architecture

Ing. Viliam Lendel, PhD.
University of Žilina
Faculty of Management Science and Informatics
Department of Management Theories
e-mail: viliam.lendel@fri.uniza.sk

Ing. Michal Varmus, PhD.
University of Žilina
Faculty of Management Science and Informatics
Department of Management Theories
e-mail: michal.varmus@fri.uniza.sk