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Russia's digital railway begins to take shape

Russian Railways is engaged in a wide-reaching programme of "digitising" its railway network in areas ranging from operations to asset management. Efim Rozenberg, first deputy director general of the railway's research institute, NIIAS, and Alexey Ozerov, head of the international cooperation department at NIIAS, outline some of the projects and achievements so far.

WITH over 45% of freight and more than 25% of passenger traffic, rail remains the single most important element of Russia's transport system.

Yet retaining this market share while ensuring continuing sustainable development requires constant enhancements to internal processes. In an effort to address this, Russian Railways (RZD) issued its Comprehensive Plan of Innovative Development for 2016-2020, which outlines plans for the widespread deployment of digital technologies across the company's operations, including rolling stock and infrastructure monitoring, traffic management and train control.

The plan offers a concept of the digital railway that has much in common with the initiatives underway in Europe such as the Shift^{2}Rail programme, 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) in May 2016.

The plan highlights the current global trend towards adopting digital technologies and processes, including the deep penetration of digital technologies in the transport sector. It also looks to utilise the Russian railway industry's considerable experience of innovative development.

While having the potential to be a game-changer for the railway industry, digitalisation is by no means an end in itself. It provides unique tools to increase transport efficiency which can stimulate the transition to a new level of industry development. For example, the widespread deployment of next-generation low-throughput wireless networks like LoRa, and the huge processing capacity offered by cloud-based technologies, can pave the way for the development of an integrated technology platform that provides decision-making support for management across all industry processes.

At the heart of this transition are new digital, data-driven business models which are based on the automation of data gathering from specific operating parameters and industrial processes. In the railway context, this amounts to the development and improvement of digital or virtual images of objects and processes. Digital images help to solve a whole range of issues. For instance, analysing and simulating the behaviour of a device's digital image, which is built using the information collected by specialised monitoring and diagnostics sensors throughout a device's lifecycle, provides access to accurate information on vital device parameters such as operating safety, resilience, and longevity.

This approach enables the development of and, if necessary, updates to technical requirements based on empirically verified data. In addition, it drastically changes the maintenance service process to one performed on a well-grounded forecast. This is especially relevant for rotating elements and components used in traction systems, engines and axleboxes which are most exposed to wear-and-tear and require constant monitoring.

Acceptance

The techniques involved are in line with the concept of the Industrial Internet of Things (IIoT) which is steadily gaining acceptance around the world. Indeed, a number of technologies associated with IIoT are undergoing tests at various of RZD divisions and facilities. This includes LoRa, which can create guaranteed wireless communications channels within 15km in the countryside and 5km in densely-developed urban areas. A LoRa-based communications network is proven to have sufficient resilience to heavy interference and an overall adverse electromagnetic environment.

RZD is also looking at and testing other low-throughput wireless communications solutions and is trialling and using a wide array of applications that use wireless sensors to collect information and offer remote transmission within the railway environment as part of the concept of IIoT. Promising results are expected from wireless sensors for railway automation devices such as signals, relay cabinets, trackside equipment, and hot box detection systems.

All of the information relating to the operation of railway facilities, which is collected by a distributed network of sensors, is transmitted to RZD's respective automated control systems which are connected to a secure corporate data communication network.

The distinctive feature of the chosen concept of IIoT is the deep vertical and horizontal integration of automated industrial control systems. RZD has assigned the so-called Intelligent Railway Transportation Management System (ISUZhT) as the integration platform for all automated traffic management systems. The platform is currently undergoing trials and is based on a multiagent approach. This relies on the principles of artificial intelligence to integrate and process big data from traffic processes, and could include the current status of signalling systems, the speed and weight of trains, the location of locomotives, trains, wagons, speed restrictions per line sections, and the technical condition of rolling stock and automation devices.

The ISUZhT project assumes that the rolling stock acts as a sensor. It should be noted that in the 1990s the Russian railway industry was one of the first in the world to equip new rolling stock with a train protection system integrated with GPS/Glonass satellite receivers capable of transmitting train position and other data via radio to centralised traffic control facilities. Currently more than 16,000 of these ATP onboard units have been installed on vehicles running in Russia and CIS countries.

Furthermore, the latest-generation Russian EMUs such as the Lastochka and Sapsan are equipped with special onboard information and measurement systems for diagnostics and monitoring, which offer complete automatic supervision of the status of infrastructure during everyday operations. With continued deployment of this technology, in the medium-term we can expect to transition to an infrastructure diagnostics regime which no longer requires the use of flaw detection cars and other autonomous technologies.

Reliable information on the condition of railway infrastructure and facilities is one of the key components of other intelligent data processing and analysis systems developed and deployed by RZD. This includes top-level decision making support solutions, epitomised by RZD's URRAN system, which is designed to provide comprehensive management of risks, and offer dependable estimates of the cost of railway facilities at all life-cycle stages.

The URRAN common corporate hardware/software platform already implements the following functions based on the automation of data collection and application:

- automation of the initial processing of statistical data on railway infrastructure and rolling stock equipment failures

- identification of quantitative values of operational dependability and safety indicators of infrastructure facilities
- quantitative evaluation of infrastructure and rolling stock service activities subject to failures and organisation of maintenance and operation of infrastructure facilities
- supervision, comparison and motivation of associated business units' activities based on the indicators of operational dependability and safety
- evaluation of compliance of the actual indicators of operation dependability and safety within standard norms
- preparation of estimated data to support recommendations for risk reduction
- identification of vulnerable facilities based on risk estimation
- preparation of draft work plans for infrastructure and rolling stock maintenance, and
- preparation of investment in distribution projects for railway facilities that present the most problems.

URRAN facilitates the implementation of a new approach to condition-based maintenance of railway infrastructure and rolling stock. Furthermore, various wireless sensors installed on rolling stock encompassing a wide range of digital subsystems, including acoustic sensors and technical vision facilities, can supplement fixed integrated inspection stations. As a result, the technology not only identifies wear and tear or the critical condition of components, units and facilities, but enables substantiated forecasting of the deterioration of equipment, informing decision-making when assigning maintenance activities.

One of the priorities for digitalisation in the Russian railway industry is the use of geoinformation solutions to offer widespread deployment, automated generation and updates to railway track digital models.

For several years, this technology has been tested by RZD in a range of operational environments. For example, use of digital track models, which offer high-accuracy coordinate referencing of infrastructure facilities, has facilitated the automation of track maintenance and tamping operations which has significantly reduced costs and improved the quality of activities performed. This approach also offers the possibility of assigning maintenance operations with an accuracy of within 1cm, and RZD is now aiming to deploy this technology across its network.

Further development is based on an integrated spatial data system of railway infrastructure, which is now under development, and a highly accurate coordinate system intended primarily for design, construction, maintenance and operation of infrastructure.

The solution was used in the large-scale reconstruction project for the Moscow Ring Railway (MRR) which was successfully completed in September 2016. The 54km former freight line was rebuilt to reduce the pressure on the city's passenger transport infrastructure with 31 stations refurbished or newly built, including 17 transfer hubs with access to metro stations, bus stops and commuter rail stations.

The reconstruction project involved close management of mixed passenger and freight traffic. A complex train separation system was deployed, which is based on automatic block and uses audio frequency track circuits integrated with computer-based interlocking in stations and ATP systems on board trains. This offers automatic train separation using the moving block principle and can operate in two modes: light signal mode for operation of freight trains of a specified mass and length; and light signal-free mode for higher-speed operation of EMUs with a minimum headway of three minutes.

The system provides automated train control according to the target schedule and automatically identifies and solves possible conflicts by calculating and executing an alternative schedule. In the event of a delay this process also attempts to recover lost time. Train position and speed are supervised using GSM-R and an integrated positioning system based on satellite navigation devices is part of the onboard train protection system.

Driverless trains

The concept of the digital railway is inevitably closely connected with fully automatic and driverless trains. So-called smart locomotives and smart trains are considered the future for rolling stock and RZD is actively developing this technology, with prototypes already undergoing tests at some trial sites.

For example, in 2015 at the Luzhskaya freight terminal on the October Railway, successful tests were carried out of an automatically-controlled shunting locomotive. An additional technology for controlling the shunter from a remote operator workstation is now being tested at the same site.

Here the shunters are controlled via a digital radio channel with continuous automatic supervision of their location using GPS/Glonass-based satellite navigation with augmentation (differential correction) and the digital yard layout model. The purpose of this project is to develop the procedure for simultaneous control of several shunting units from a single remote workstation.

Another innovative solution developed for train positioning is the use of vibroacoustic track monitoring. In this system train detection is based on fibre optic sensing to identify the precise coordinate positioning of trains on open lines between stations.

The technique requires converting a spare fibre in the fibre optic cable into a distributed sensor, and works by identifying changes in the signal reflection from the cable as rolling stock passes along the line. This is carried out by a reflectometer located at the trackside, with differences between reflectograms providing an accurate measurement of the position of a specific vehicle. The system permits rolling stock supervision within 40km of the reflectometer and the central computer unit's location with the positioning accuracy no worse than 15m.

The purpose of this project is to create a low-cost and low-maintenance train separation system for low and medium-density lines that can minimise or eliminate the use of trackside signalling devices between stations.

Implementing this system also increases the capacity of single-track lines equipped with semi-automatic block systems by utilising a coordinate positioning of trains on open lines. As a result, it reduces the capex and opex of modernising trackside devices on single and double-track lines with medium traffic density.

The new train separation system can accurately supervise train movements along a line, and can generate control commands according to permitted movement parameters for each line section and transmit these via radio directly to the train. The solution also offers constant monitoring of the right-of-way and can easily identify intruders and other activities taking place along the line. RZD is now performing tests of this technology on one Moscow Railway line, which includes establishing interfaces between train control devices and automated monitoring and diagnostics systems.

Digitalisation of Russia's railways is not a goal in itself but provides a powerful tool for increased traffic efficiency. Greater efficiency will inevitably follow widespread deployment of these technologies which, as the examples show, are already beginning to inform and improve the control and monitoring of railway assets in Russia. Judging by these encouraging initial results, it is safe to say that further breakthroughs are expected in the years to come.