Digital Transformation in Railway Transport

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Abstract

Digital transformation is a comprehensive way of moving to the new ways of operating, new business models using digital technologies. This also applies to rail transport, which itself can gain a lot from the introduction of new solutions. Digital transformation in rail transport can have a positive impact on existing customers and generate the interest of new customers in this mode of transport – by creating new opportunities as a result of digitalisation, thus increasing the comfort zone of customers within the transport services offered. Technological development and digitalisation lead to the improvement of rail transport, allowing this mode of transport to develop, increase its competitiveness in relation to other forms of transporting people and goods. The aim of this chapter is to discuss the directions of the digital transformation of rail transport. The research method was the analysis of available indications within the literature, and the analysis of practical experiences in the introduction of solutions related to the areas of the digitalisation of rail transport. The conclusions indicate the importance of the digitalisation of rail transport and processes ensuring digital support for the transport process.

Keywords: rail transport**,** digital transformation, digitalisation of rail transport

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Introduction

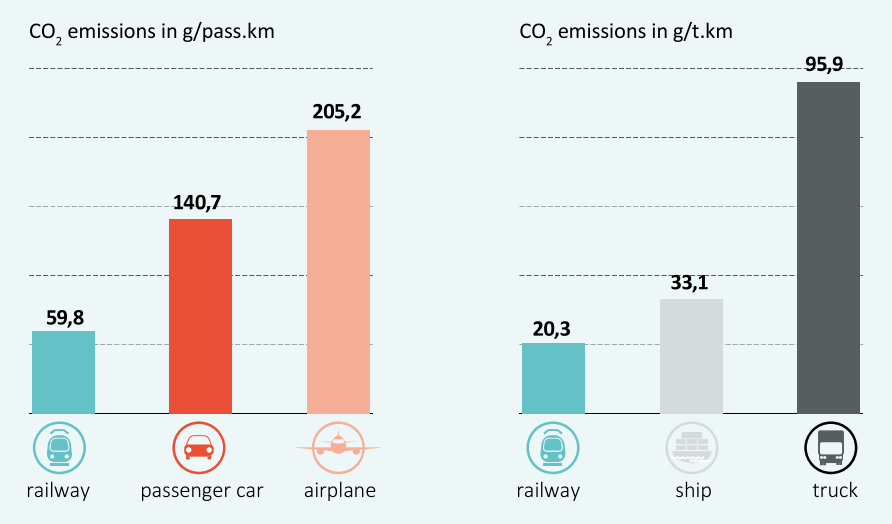
Contemporary business has been constantly changing, evolving and transforming due to the development of cutting-edge digital technologies and new business ideas. Transformation, according to Mazurek (2019, p. 21), is the evolution of a particular system, often a large-scale one. Transformation related to the impact of digital technologies on social and economic systems may be called digital transformation. Digital transformation refers to the processes and strategies where the use of digital technologies serves to radically change the way the businesses operate and serve their consumers. The core of digital transformation is the introduction and effective implementation of digital technology-based solutions. It is closely related to the idea of digitalisation. Digitalisation means the adaptation and increased employment of digital or computer technologies by organisations or economic sectors (Pieriegud, 2016, p. 12). It is caused by the fact that each organisation or sector is relying more and more on data and technologies in order to increase the effectiveness of its operations and to ensure value for their consumers. This also refers to transport. The 2020 European Strategy for Sustainable and Smart Mobility (European Commission, 2020) defines the future of transport in the European Union as a system which is effective, smart and accessible for all the interested potential users. Some of the key actions that are expected to support transformation in this area, are the rigorous cut-down on a negative impact on natural environment as well as combining different modes of transport into one coherent system. Therefore, the tasks which the European investment and regulatory policy face today do not only mean the redevelopment of infrastructure or promotion of new environmentally-friendly energy carriers. They also imply actions oriented at the improvement in the effectiveness and integration of different modes of transport. It is thanks to them that the European transport is expected to transform into a common, competitive, affordable, safe and smart system. Additionally, the expected results of the announced transformations are to be seen already towards the end of this decade. The European Commission states that by 2030, the European transport will be characterised by:

- fully digitised information in logistic chains
- wide use of integrated ticket systems
- general automation of transportation operations (European Commission, 2020).

The rail transport is to be an integral part of the thus defined transformation of the transport sector, mainly thanks to its ecological advantages which are presented in Figure 1.

Railway transport, for ecological and other reasons, is supposed to improve its competitiveness and attractiveness on the market as well as considerably increase its share of it. Research (IBRIS, 2021) shows that the railway clients want the rail-

Figure 1. Carbon dioxide emission in the EU transport, by specific modes of transport for 2016



Source: *Railway Transport in Numbers*, ProKolej Foundation, Warsaw (2021); see also: Report *The Rail for Climate – Climate for the Rail*, ProKolej Foundation, Warsaw (2021).

way transport to be climate-neutral. If this happens, the respondents declare to increase the use of the railway transport. This is closely connected with the programme of green railway, which means the transition of transport towards the low-emission (UN Global Compact Network Poland, 2021) transport. The digitalisation of the railway transport operations and its relations with the client is supposed to facilitate this transition and be the backbone for electromobility in Poland (Jagiellonian Institute, 2017). This chapter presents the directions of digital transformation in railway transport.

Railway Transport in Digital Economy

Digital economy, as indicated by Śledziewska and Włoch (2020, p. 9), is developing before our very eyes. This development is fuelled by intensified digitalisation processes, i.e. the widespread adoption of digital technologies by various businesses. According to Schallmo and Williams (Mazurek, 2019, pp. 22–23), digitalisation means changes in the way businesses operate and in the functioning of business models; changes which are introduced on the basis of newly acquired knowledge and through digitalisation activities. New technologies, such as the Internet of Things, cloud computing, artificial intelligence, etc., speed up the datafication process (Śledziewska, Włoch, 2020, p. 9), i.e. the creation of digital spheres of the real world, intensify the networking process, thus facilitating personalisa-

tion. Digitalisation appears as the tool which not only ensures the necessary connection between the real and virtual worlds, but it also becomes the prime engine of innovation and changes that affect all sectors of economy.

Under the influence of progressing digitalisation, there is more and more competition on the market between traditionally operating businesses and the ones that employ new business models, and thus can offer:

- new products and services
- joint offers which combine sectors and suppliers that have been unrelated so far
- extra services and products offered along with a transaction
- shared offers and models.

According to the report by Deloitte (*Digital Marketing Newsletter*, 3/2021), digital transformation requires the transformation of business models and products, the optimisation of corporate governance, the creation of digital work environment and engagement of clients in a variety of communication channels. Information and communications technology has been used in the railway since the 1970s. In 2016, the following areas were identified as primary for the adoption of digital technologies in the railway transport (CER, UIC, EIM, 2016):

- creation of networked railway which uses reliable connectedness, ensuring the safety, efficiency and attractiveness of the railway services
- increased customer satisfaction thanks to added value for passengers
- increased railway capacity, reliability and efficiency through the automation of processes
- improved competitiveness of the railway through the optimal use of data.

In the case of the railway transport, it did not only mean organisational transformations but also comprehensive remodelling of the structure and business processes of whole organisations. By this, mobility-related services, as well as the whole logistic-transportation chains, have been reshaped. With regard to this, the implementation and development of digital technologies result in the redefinition of customer relations, organisation of work, the exploitation of resources and marketing. This is explicitly highlighted in the document entitled *Digital Trends in the Rail Sector*, prepared by the Association of the European Rail Industry, or in the Strategy for 2021–2024, adopted by the regulators of the railway transport market (IRG) of the EU member states (*IRG-RAIL Strategy Document 2021–2024*, 2021), or in the prospect of the railway by 2030, offered by the International Union of Railways (UIC, 2021). The IRG Strategy states, among other things, that "digitalization should not be limited to infrastructure managers or railway undertakings, but should also be directed to end users. This means having powerful internet hubs, offering accurate location information on phones and the ability to receive real-time updates. Infrastructure managers and railway undertakings need to work together to provide trav-

elling information seamlessly integrated and suited to users' needs in reaching their destination regardless of the chosen provider or mode of transport. Agents in the railway sector need to work together to exchange the necessary timetable and real-time data under open standards to improve the end-users' travel experience" (*IRG-RAIL Strategy Document 2021–2024*, p. 12) and to carry out the orders to deliver the freight to their destination points. Here also, five main trends of digitalisation in the railway transport (Poliński, Ochociński, 2020, pp. 137–148) are worth noting, i.e.:

- connected commuter – access to the internet during the journey
- preventive maintenance of the rolling stock – maintenance dependant on the data transferred on an ongoing basis by data electronic systems without the wear and tear of particular components, which adds to the reliability of the rolling stock
- mobility as the service related to the easier planning of a journey
- automation and interoperability of the traffic management systems, i.e. the systems in which the vehicles are started with no participation of the operative personnel at all
- the Internet of Trains – increased safety of the railway traffic, decreased operative costs and improved quality of the offered services.

Information and communications technologies are widely applicable in the networking of all the operation areas of the railway transport: designing and planning, production of the rolling stock and the elements of infrastructure, implementation of projects, management and railway traffic operations control, maintenance of the assets, organising the transportation process, contacting business partners and implementation of the internal business processes.

Solutions offered by modern technologies are becoming a component included in the creation of new business models and market strategies because they have the key role in performing tasks in the new economic conditions – in digital economy.

Furthermore, they do not only permeate all the spheres of the current railway businesses, but they are also engaged in the preparation and implementation processes for further innovations. Digital transformation affects the vast majority of spheres where the railway transport entities operate, among others in (Sobczak, 2016; Gajewski et al., 2016):

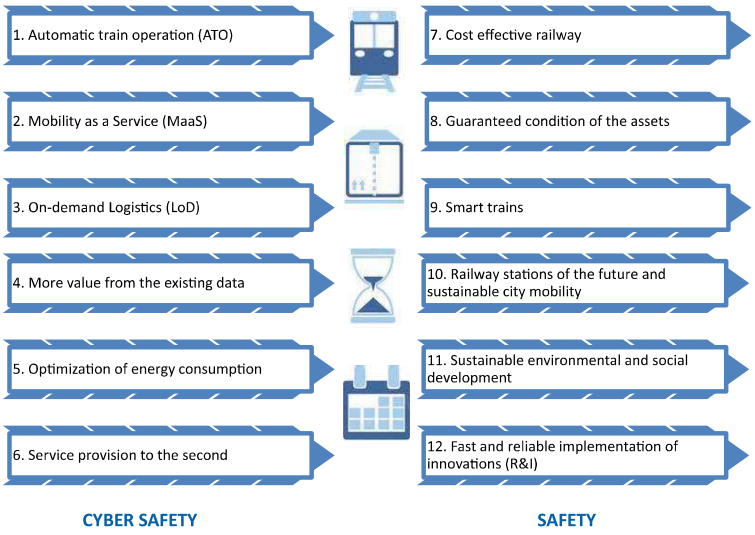
- structure and business model
- operation processes which form the organisation and the work environment; also, mechanisms of management and monitoring of effectiveness
- forming customer relations, including research on the market needs, forming communication channels and provision of tools for self-service.

Apparently, the potential of digital solutions in the railway transport turns out to be very big – from the smart infrastructure and rolling stock, through the supervision over the operations and management on a daily basis and interactions

with clients, to designing one's own innovations. Railway businesses develop and implement digitalisation programmes for their operations through the innovation-supporting projects which they initiate in collaboration with researchers and experts from the railway sector.[3]

An excellent example of such cooperation comes from the Europe Horizon 2020 programme which was designed for execution and within the financial framework forecast for 2021–2027. The basis of the Europe Horizon programme has been defined as the so-called 12 key capabilities (see Figure 2) which cover most areas related to broadly defined passenger and freight transport.

Figure 2. 12 key capabilities of the railway, according to the Europe Horizon for 2021–2027



Source: own materials of PKP S.A., Warsaw (2021).

From the railway transport perspective, the biggest potential lies in digital technologies and information and communications technologies concerning the following:

- Internet of Things

[3] Transformation in this area is also aided by such initiatives as the research and innovations programme Shift-2Rail, which helps the cooperation of the public and private sectors or the sectors' platforms, conducted by, among others, UIC or PKP S.A., effective innovative partnerships with other corporations, railway entities, and European entities from other sectors of economy and with Polish subcontractors, such as PKP Informatyka or the Railway Research Institute, to conduct international projects: Shift2Rail, In2Stempo and MaaSive – subsidised from the EU funds within the Horizon 2020 programe. PKP S.A. participates in these projects in the consortium EUROC (European Railway Operational Community Consortium), which comprises entities from the railway sectors of Austria (ÖBB), Finland (FTA), the Netherlands (ProRail), Portugal (CP and IP), Slovenia (SŽ), Switzerland (BLS and SBB) and Turkey (TCDD).

- cloud computing
- Big Data recording and analysis
- robotisation, autonomous vehicles
- new digital products and services that are becoming integrated with the transporters' operations
- employment of autonomous and near-autonomous vehicles.

New digital products and services are now becoming an integral part of the carriers', infrastructure administrators', producers' and service providers' operations. Thus, they add value for all the participants of the transportation process, from production companies, through the construction sector, infrastructure administrators, carriers and their subcontractors, to the clients – varying from institutions and transport organisers to public administration. During the designing phase, digital tools allow for the optimisation of the processes, such as the preparation of investment, selection and configuration of particular elements and their parameters, as well as for the planning of the development processes. This enables the optimisation of the financial outlays, work and time, not only at the preparation and development stage, but also during the subsequent operation stage.

Digitalisation of the External Relations and Communication Channels

Social and economic digitalisation processes prove to be crucial in the formation of transportation services. Contemporary mobility demands effective time usage and functioning in two parallel worlds: metaspace and cyberspace – both at work and at home. Therefore, expectations rise about the analogous internet accessibility during the journey. Thus, cutting-edge mobile devices as well as expanded communication networks, which ensure the exchange of digital, vocal and visual data between the users and the resources stored in the cyberspace, are becoming the part and parcel of the transportation service.

At the first stage of digitalisation in the railway sector, substantial progress could be observed in regard to communication with clients due to the following factors:

- expanded and reinvented websites of carriers
- mobile applications with access to the information about the train timetables in real time and the possibility to buy a ticket and extra services
- ultra-modern systems of dynamic information for passengers on a train, at train stations and stops, which use tools to forecast the development of the situation on the basis of the timetable, information about the current traffic and train parameters.

Gradually, more and more carriers, especially in the long-distance traffic, have already added to this list by starting their own digital platforms which are available for passengers on the trains. They are offering a broader and broader range of services and entertainment which raise the standard of a journey. These include, among others, real-time information about the journey, a range of extra services, such as a virtual library of books (e-books), music, audiobooks, films, newspapers and magazines, computer games, social communicators (discussion groups and chat groups).[4] Table 1 presents examples of digitalisation in the railway transport of passengers.

Table 1. Digitalisation areas in the passenger railway transport

Technology	Digital idea	Examples of use
– Broadband access to the internet – Mobile internet – Big Data – Cloud computing	– Connected commuter – Intelligent stations – Smart ticketing – Mobility as a service	– Access to the internet during journey (3G/4G/5G) – Mobile applications with real-time information about trains and the option to buy a ticket – Infotainment systems on board of trains and at the stations – A variety of applications integrated into one system through the inter-operable product service interface – Real-time Passenger Information Systems – Automation of the ticket selling and information providing processes – Applications to plan an intermodal journey

Source: J. Pieriegud (2019). *Transformacja cyfrowa kolei*, p. 52.

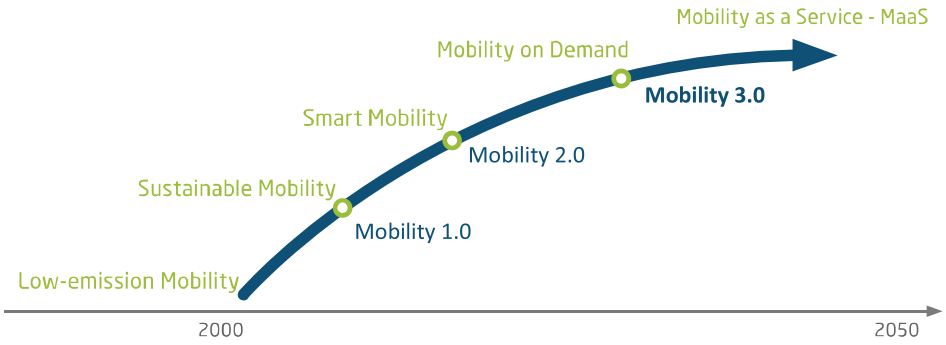
Access to Wi-Fi and extra services to accompany the journey are also available at the train stations. Systems of virtual information provide the train timetables, the platform to buy train tickets, the maps of train stations with shopping and service zones, maps of the surrounding areas, information about sports and cultural events (Radzikowski 2018). The need for continuous access to the internet and various communication channels, the use of social media, among others, gives rise to the ever more individualised needs regarding personal mobility and macrologistics – such as, for instance, supply systems and courier deliveries or smart contracts in the transport of freight. This trend is met with the rising need for new products and services. This also refers to the needs and communication behaviour of consumers and consignees of cargo. The transport of passengers realises so-called smart mobility via the pursuit of optimal configuration, connection and exploitation of different modes of transport, i.e. the inter-modality of the transport system.

To successfully meet the said expectations, certain new concepts of mobility have been offered and they adopt a variety of formulas: on-demand mobility, mobility at any time, network mobility, shared mobility, integrated mobility and e-mobil-

[4] The fee and access to particular packages is subject to the travel class.

ity. Each of the new models is connected, which means it offers access to the internet, as well as information and communications systems. This allows for fast planning of the most convenient journey, bookings and paying the fare, and eventually travelling, with the up-to-date information about the journey. What is more, the mobility-on-demand model does not only provide for the transportation service, but it also has an economical component by which the users only pay for the services that they actually use (pay-as-you-go). In different configurations, they constitute further stages of the advancing revolution in transport, illustrated in Figure 3.

Figure 3. Stages of transport revolution



Source: J. Pieriegud (2019). *Transformacja cyfrowa kolei*, p. 26.

Contemporary mobility, i.e. the idea of mobility as a service is the model of distribution of transport services which assumes the fulfilment of individual transport needs through the complex and universal digital platform (Zawieska, Pieriegud, 2018).

Digital solutions are also implemented in the railway freight transport. There is growing eagerness to develop technical and technological innovations which improve transportation processes (e.g. organisational and legal) in situations such as border crossing. Examples of digitalisation areas in the railway freight transport are presented in Table 2.

Table 2. Digitalisation areas in the railway freight transport

Technology	Digital idea	Examples of use
– Internet of Things – Big Data – Cloud computing – Automation and robotics	– Logistics 4.0 – Freight as a service (FaaS) – Intelligent freight car – Logistics platforms	– Real Time Train Tracking System – Electronic consignment notes, e.g. digital CIM/SMGS consignment note and e-invoices – Digital cargo booking platforms – New business models to organise transportation – Smart contracts (blockchain technology)

Source: J. Pieriegud (2019). *Transformacja cyfrowa kolei*, p. 52.

The POLSUW system is an example of such a technological innovation. It is involved in the production of railway trucks which can automatically change the wheelbase, according to the width of the track gauge, while the train is running; see Picture 1. This system will considerably shorten the proceedings and will cut transportation costs on the borders with different railway systems and different widths of the railway gauge.

Picture 1. POLSUW model of the railway truck

Source: own elaboration.

One example of innovative implementation from the organisational and legal area is the common consignment note CIM/SMGS (Gajewski et al., 2018). This document is a uniform consignment note issued to carry freight and it is used by countries which have different regulations regarding international transport (SMGS and CIM) (Antonowicz, 2021). This consignment note is one for the whole route and there is no necessity for repeated registration wherever the transport law changes. It is recognised as the customs document and it simplifies the procedures related to the transportation of freight by rail across borders. Currently, CIM/SMGS is used by railways in 18 countries. The implementation of this consignment note has brought positive results for the railway transport, among others, the following (Antonowicz, 2021):

- considerably shorter stoppage time of trains at border stations
- improved quality of service and lowered costs
- time saving as no re-registration of documents on borders is necessary
- lowered costs as there is no need for renewed issuance of documents to continue transportation in the areas under a different transport law
- avoidance of documentation inaccuracies and errors committed as a result of renewed registration of shipping documents; ensuring a high level of concordance with legal norms during transportation for its participants
- faster delivery due to shortened stoppage time of the freight at renewed shipment sites.

In July 2019, the electronic version of the consignment note CIM/SMGS was implemented as exploitation practice in international transport. Railway organisations are cooperating over its introduction into cross-border container transport along the China-Europe-China route. A concrete example of digitalisation is smart contracts. A smart contract is a digital representation of principles or processes which function in a given business organisation. They regulate the way and course of making business deals (Wodnicka, 2009, pp. 43–54).

A good example is offered by the Russian Railways, which started testing the product called "on-platform monitoring of smart contracts for railway transport of freight. Distributed ledgers are based on the technology of blockchain for business processes in transport and logistics" back in 2019. This service ensures support in making contracts for the main operations of transport and logistics activity and for mutual financial settlements between the participants of the transport process. The platform obtains essential data from 7 cooperating information systems. These systems generate data regarding the main operations with train carriages and containers, including applications, formation and inspection of train carriages, freight and clearing of carriages, departure and tracking the freight on the way to its destination. Parallelly, the relations that develop between the operator and the carrier are regulated by the existing laws and bylaws. Should a party fail to comply with a contractual obligation, the system will automatically impose the stipulated fine. By this, a non-standard, mutually acceptable mechanism of working is ensured.

Digitalisation of Organisations and Operation Processes

The use of digital data for diagnosing and monitoring, obtained from big databases, changes the approach not only to offers for external clients, but also to offers for maintenance and management of operations. More and more systems and subsystems are integrated with elements of infrastructure, machines and vehicles. By this, the operated rolling stock[5] becomes a source of information about the condition of infrastructure and vice versa, the infrastructure makes use of the elements which enable diagnosis of the rolling stock running along this infrastructure. More and more perfect digital tools, including information systems which make use of the parameters that report about particular units and indicate their subsequent level of wear and tear, lead to the development and implementation of the preventive maintenance models. Making use of the effective integration of databases and busi-

[5] An example of such a solution is ASDEK systems which detect failures in the rolling stock. They monitor the running vehicles' sets of wheels, they automatically check, via non-contact detection, the dynamic reaction on the track, the temperature of bearings and the elements of the brake. This helps to automatically detect and eliminate the cases of damaged or overloaded rolling stock. As a result, they help to eliminate failures, raise the security level and prevent damage to the elements of the infrastructure and the rolling stock.

ness processes of the infrastructure administrators, carriers and logistic and IT systems operators, the rolling stock manufacturers may offer their customers such digital services as:

- monitoring of the condition and the location of the vehicles and their components in real time
- remote diagnostics
- analysis and definition of causes of malfunction
- preventive algorithms and detection of breakdowns.

Digital access to data redefines the processes of the infrastructure and the rolling stock maintenance. The analysis of data read by the diagnostics machines and sensors, located in the key system nodes, can power the computer centres and help to detect potential breakdowns. Thanks to the access to big databases and the tools of a mathematical model, potential problems are detected in time for early intervention. Detailed information with prediction enables one to indicate the elements which may go out of order and thus prevent potential malfunction. As a result, the system guarantees high reliability which decreases the need for operation reserves and increases the effectiveness of the system.

Table 3. Areas of digitalisation in the railway system operations

Technology	Digital idea	Examples of use
– Internet of Things – Cloud computing – Big Data – Automation and robotics	– Infrastructure 4.0 – Self–aware infrastructure – Self–aware rolling stock	– Infrastructure monitoring systems – Predictive maintenance – PM – Monitoring of the condition of the infrastructure and the rolling stock

Source: J. Pieriegud (2019). *Transformacja cyfrowa kolei*, p. 53.

Generation of the added value of new digital services is possible thanks to the cloud-based platform to analyse data and the Internet of Things, which allows for the direct communication of particular parts and resources of an organisation.

In the railway transport, the development of the autonomous systems has become common in the traffic management on a particular infrastructure dedicated to the passenger traffic. For some time now, there have operated automatic underground lines and light rail transit. They function on the basis of automation which accounts for the integrated process of the traffic management and its operation.[6]

[6] International standard IEC 62290-1 defines four grades of automation (Grade of Automation – GoA) in the rail transport. The highest, fourth grade refers to the system in which the vehicles are set into motion without any crew onboard.

The most prevalent implementation of this model is autonomous systems employed in underground trains.[7] Innovative solutions regarding the railway automation bring about an array of benefits for the railway system:
- increased level of the infrastructure trafficability
– improved punctuality
– increased level of traffic safety
– increased energy efficiency
– reduction of operating costs
– reduced impact on the environment and the surroundings.

Areas of digitalisation in railway traffic control are presented in Table 4.

Table 4. Areas of digitalisation in railway traffic control

Technology	Digital idea	Examples of use
– Broadband access to the internet – Mobile internet – Internet of Things – Cloud computing – Big Data	– Connected trains – Internet of Trains	– Infrastructure monitoring systems – Automated Train Operation – Implementation of standards regarding cybersecurity (NIS Directive)

Source: J. Pieriegud (2019). *Transformacja cyfrowa kolei*, p. 53.

It is worth emphasising that the implementation of the automated train operation on the underground lines results in savings in regard to the number of the onboard crew, but, above all, in the improved security resulting from the elimination of human error. Even more, there is better capacity performance and consequences of trains. Another stage of the development of this model consists of the combination of three systems: that of dispatcher, security and communication into one complex and smart system of traffic management, which aids real-time decision-making. This solution allows for the ultimate introduction of automated train operation to regional, long-distance and freight trains. Due to the integrated information about the infrastructure and the condition of the vehicle, the engine driver gets left out of direct train driving. The train operating system calculates and sets the appropriate characteristics of the train running, optimises it in line with the defined timetable and energy consumption.

[7] According to the UITP data, in 2018, in 41 cities all over the world, there were 62 fully automated subway lines of nearly 1,000 km length, compare M. Darowska, J. Grzeszak, D. Sipiński, *Autonomiczny transport przyszłości*, Polish Economic Institute, 2020.

Digitalisation in the Railway Transport on the Example of the Russian Railways Strategy

The Russian Railways belong to the biggest railway organisations in the world.[8] In 2019, they approved the digital transformation strategy of the company by 2025 and they implemented the Digital Railway project. The Digital Railway project run by the Russian Railways means digital environment in which the information is the resource which defines processes, management model and available services. Its aim is to improve the quality of transport and logistic services rendered with the use of digital technologies. The structure of digital railway is presented in Picture 2. Special attention in the project has been paid to digitalisation and information technologies. The project includes key directions of information system development in the Russian Railways and they are:

- creation of information space for freight transport and logistics in order to increase their profit-earning capacity
- creation of information space for passenger transport to increase its profit-earning capacity
- creation of complex digital technologies to organise the transportation process (Digital Railway) in order to improve effectiveness of the railway transport and infrastructure
- creation of one integrated and automatised operation system, optimisation of corporate systems of company management, analysis and development of reporting in order to increase profit-earning capacity of its overseas activity, increased effectiveness of the social sphere and governance.

The strategic document related to the digital transformation describes the conceptual foundation and principles of company transformation in digital economy. It sets priority spheres for digitalisation, such as the substitution for imported IT as well as resources and technologies, which are essential for making changes.

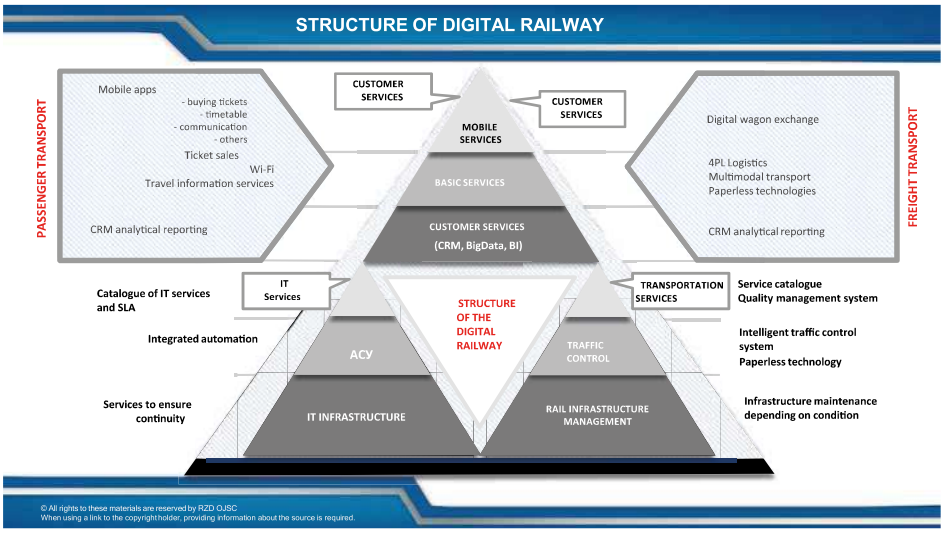
Pursuing the strategy of digital transformation is not only supposed to aid the introduction of innovations and breakthrough technologies in the Russian Railway Holding. It is also expected to change the corporate culture, increase performance and start new business processes, as well as extend the range of services offered on the market by entities from the Russian Railways Holding.

One of the main principles of the strategy will be to establish eight digital platforms – sets of related technological solutions intended to facilitate the interaction of the transport market participants. They include:

- multimodal passenger transport

[8] Essential information about the Russian Railways can be found, e.g. in the Report of the Activities of the Organisation for Co-operation between Railways for 2020, OSJD, Warsaw (2021).

Picture 2. Structure of digital railway



Source: Charkin (2019).

- multimodal freight transport
- transport and logistic nodes
- line infrastructure operator
- logistic and e-commerce operator
- management of the transportation process
- railway rolling stock
- non-production processes.

The strategy provides for running over 50 projects in these areas as well as the use of domestic advanced innovative solutions based on such digital technologies as the storage and management of Big Data, distributed ledgers, quantum computing and others. These digital platforms are interconnected technological solutions serving the participants of the transport market to interact. What is more, basic platforms are created as structures of interconnected technological solutions which ensure support of information technologies such as the Internet of Things, Big Data, smart systems which implement, among others, machine learning methods, virtual reality, as well as new technologies for data transmission such as quantum communication. Tentative calculations by the Russian Railways show that, only due to the introduction of digital technology, the volume of freight will have increased by 70 million tonnes by 2025. Customer Relations Management system (CRM) will help to translate into electronic form up to 90% of the correspondence with freight dispatchers. The electronic trade platform will become "the window" to render services of freight delivery, smart contracts will accelerate and improve

the effectiveness of business processes. CRM and the system of managing customer data are the basis to introduce better B2C services via the organisation website. When it comes to the management of the rolling stock, it is switching from the accounting systems to smart management that poses a challenge for digital transformation. The introduction of IT will accelerate the planning of the transportation process thanks to the operation update. This will also decrease dependency on the human factor, for instance, at the railway station dispatch area. The bases of railway engines will turn into "digital locomotive depots" where smart train engines will be serviced within trusted IT environment. The Russian Railways, together with their adviser, have launched a project which consists in the use of IT solutions to make a machine see in order to collect data from the sensors located on the rolling stock and to analyse these data in real time. In order to manage the life-cycle of the whole railway infrastructure, the Russian Railways have created a special line infrastructure operator which will employ methods of building information modelling (BIM). The following ultimate digitalisation level is planned to be gained by 2025:

- introduction of platform solutions integrated with production systems of the Russian Railways, their coordination and interaction with digital solutions of the whole transport system and the possibility to make digital services on this basis
- establishment of electronic channels of interaction with the market (passengers, freight forwarders, service agents), federal executive bodies and the participants involved in transportation along the transport corridors across borders
- integration of technological processes of the Russian Railways with the Internet of Things, processing Big Data, distributed ledgers, digital modelling and artificial intelligence
- creation of new generation mobile job offers and electronic management of documents in production and management processes
- modernisation of the information and communication infrastructure to ensure the guaranteed accessibility of information services
- introduction of centralised security measures, based on independent solutions, to ensure the information is secure
- formation of sustained culture of work with the use of new technologies (searching, approving, prototyping, implementation) and the development of high-tech business in the holding.

Conclusion

The growing importance of digital economy is mostly resultant from innovative technologies and consumers' growing expectations regarding the quality of service. Digital transformation is unavoidable, on the one hand, to maintain the attractiveness of the transport offer and vital, on the other hand, to maintain operating capac-

ity and competitive advantage in view of increasingly digitalised communication channels with the environment. Due to the progressive digitalisation, there is growing integration of technologies and business processes between the market operators. This corresponds with the objectives regarding the inter-modality of the European transport system. One example of inter-modality is the idea of the "door-to-door" supply regarding the transport of freight or the idea of the single ticket in the railway passenger transport for the whole route, irrespective of the railway or the carrier who actually covers a given piece of route. In railways, solutions related to digitalisation are made within the railway systems of particular companies and railway networks. Ultimately, there must be global integration of solutions between particular railway systems, both from legal and from technical perspectives. The integration and dynamics of processes carried out by railway organisations lead to the development of a new model of their functioning which is based on the fast flow of information, ensured security for clients and the high quality of service. Moreover, it facilitates the development of new business models based on the integration and management of the competencies of cooperating entities.

References

Antonowicz M. (2021). *Innovations in the railway transport*, presented at the conference *Innovative Technologies in Logistics Transport and Education*. Academy of Logistics and Transport, Almaty, Kazakhstan, 25–26 November 2021.

Antonowicz, M. (2021). 65 lat działalności OSŻD w przestrzeni euroazjatyckiej. *Railway Report*, 192 (September 2021), Railway Institute, Warsaw, 7–16.

A Roadmap for Digital Railways (2016). CER, UIC, EIM, Brussels.

Charkin, E. (2019). Presentation at TAdviser SummIT Conference, Moscow.

Darowska M., Grzeszak J., Sipiński D. (2020). *Autonomiczny transport przyszłości*. Warsaw: Polish Economic Institute.

Digital Marketing Newsletter, 3/2021.

European Commission (2020). *Sustainable and Smart Mobility Strategy – putting European transport on track for the future*. European Commission, COM/2020/789 final, Brussels.

Gajewski J., Paprocki W., Pieriegud J. (eds.). (2016). *Cyfryzacja gospodarki i społeczeństwa*. Gdańsk: Institute of Market Economy Research, Gdansk Banking Academy.

.IRG-RAIL Strategy Document 2021–2024, November 2021. *Railway in 2030* (2021). UIC, Paris.

Majewski J. (2016). Analiza doktryn współczesnej polityki transportowej. *The Research Journal of the University of Gdańsk: Transport Economics and Logistics*, *59*, 467–481.

Own materials of the Organisation for Co-operation between Railways, Warsaw 2021.

Own materials of the Russian Railways, Moscow 2021.
Own materials of the PKP Group, Warsaw 2021.
Mazurek, G. (2019). *Transformacja cyfrowa*. Warsaw: Wydawnictwo Naukowe PWN.
Pieriegud J. (2019). *Transformacja cyfrowa kolei*. Warsaw School of Economics, Siemens, ProKolej Foundation, Warsaw.
Pieriegud J. (2016). Cyfryzacja gospodarki i społeczeństwa – wymiar globalny, europejski i krajowy. In: J. Gajewski, W. Paprocki, J. Pieregud (eds.). *Cyfryzacja gospodarki i społeczeństwa*. Gdańsk: Institute of Market Economy Research, Gdansk Banking Academy, Gdansk, 11–38.
Poliński J., Ochociński K. (2020). Digitalization in railway transport. *Railway Report*, Issue 188, Railway Institute, 137–148.
Radzikowski, T. (2018). Możliwości zastosowania cyfryzacji w zarządzaniu kolejowymi przewozami pasażerskimi na przykładzie Holdingu DB i grupy PKP. *Technika Transportu Szynowego*, 6/2018, 44–47.
Report: *Green Railways – A Potential of Ecological Transport* (2021). Institute of Social and Market Research (IBRiS), ProKolej Foundation, Warsaw.
Report: *Green Railways in Poland – Climate, Energy Technology, Transport* (2021). UN Global Compact Network Poland, Warsaw.
Report: *Electromobility in Poland* (2017). Jagiellonian Institute, Warsaw.
Report: *Railway Transport in Numbers* (2021). ProKolej Foundation, Warsaw.
Report: *The Rail for Climate – Climate for the Rail* (2021). ProKolej Foundation, Warsaw.
Sobczak A. (2013). *Koncepcja cyfrowej transformacji sieci organizacji publicznych*, *"Annals" of the Collegium of Economic Analysis*, *29*, SGH Publishing House, Warsaw 2013, pp. 279–293.
Śledziewska K., Włoch R. (2020). *Gospodarka cyfrowa. Jak technologie zmieniają świat*. Warsaw: Wydawnictwo Uniwersytetu Warszawskiego.
Wodnicka, M. (2019). Technologie blockchain przyszłością logistyki. *The Małopolska School of Economics in Tarnów Research Papers Collection*, *41*, 43–54.
Zawieska J., Pieriegud J. (2018). Smart city as a tool for sustainable mobility and transport decarbonisation. *Transport Policy*, *63*, 39–50.
Zawieska, J. (2018). Perspektywy implementacji Mobility-as-a-Service w polskich aglomeracjach. In: J. Gajewski, W. Paprocki, J. Pieriegud (eds.), *Mobilność w aglomeracjach przyszłości*, Publication of the European Financial Congress, Sopot, 30–49.