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# ICT in the Polish Railway Industry

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**Summary**

The article intends to discuss the impact of the development of IT and logistics systems on the development of ICT networks in the context of practical application in the area of transport, especially in the area of railway transport in Poland. At present, PKP PLK is involved in the construction of a teletransmission network, to be used mainly with ERTMS. According to the author, development of the network should be planned in such a way that this network is able to satisfy the current and future needs of all railway companies in the area of data transmission, making it possible for such railway companies to extend their range of ICT services to include other forms of transport. Systems of railway traffic control should be established within a physically isolated fibre-optic network (isolated fibres in fibre-optic cables).

**Keyword:** Broadband ICT networks, 5G technologies, ICT in the railway industry, Internet of Things (IoT), Physical Internet (PI)

## 1. Trends and directions of development of IT solutions

The developing IT solutions are currently becoming the main, and also indispensable, tools in operating a business. It is especially important to make use of the whole potential of IT in network-based enterprises. Such enterprises include almost all railway companies, such as PKP PLK, carrier companies (offering passenger and freight transport services), and other rail and road transport companies.

Contemporary IT solutions offer an increasing level of functionality and performance with a decreasing amount of investment and operating costs at the same time. Right now, it seems that CC *(Cloud Computing)* technology plays the main part in this context because of its great performance, accessibility and the offered level of safety.

The advantages of CC include its ability to grant accessibility, performance and safety to different systems with a simultaneous reduction in costs resulting from consolidation, virtualization, automation of the provision of services and management, and economies of scale. Moreover, CC technology offers many services to many entities working with the same providers and taking advantage of the same solutions, e.g. SaaS *(Software as a Service)*[2]**,** PaaS *(Platform as a Service)*[3], and IaaS *(Platform as a Service)*[4] [7]. Each of these services decreases the costs of use of the client's ICT systems – there is no need to purchase hardware or software licenses, to install, maintain and upgrade installation versions, software licenses, maintain or upgrade IT systems, etc. The client pays for each instance of use of a given service, and gets access to such a service on demand. SaaS, PaaS and IaaS users have access to the latest IT solutions and technical resources at quite affordable prices, which they wouldn't be able to take advantage of if they had to buy and install particular elements of these solutions at their own cost.

The shift of IT towards a private, hybrid or public cloud environment is not a fad, but is motivated by real advantages stemming from further steps of implementing a cloud model, i.e. consolidation, virtualization, automation, self-service and optimal management, etc. [11].

The volume of online telecommunication traffic is changing dynamically. The increase in its volume is said

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[2] It is a service that involves providing the client with software features they need through the Internet by a selected provider. The client is granted access to the functional tools they need – which do not have to be interconnected within a single interface. All applications run on the provider's server.

[3] It is an external service involving provision of an IT platform and a complete set of solutions related to the operation of the platform, facilitating dislocation of applications without the need to incur costs and perform activities related to the purchase thereof and managing the hardware and software required to use them, and costs of upgrades.

[4] It is a fully external service involving provision of an IT infrastructure – unlike in the case of the internal model, requiring initial investments in the establishment of such an infrastructure. The client, instead of buying servers, software licenses and data centre space, etc., purchases only the required service, and the provider that the service has been bought from makes sure that it works properly.

to amount to approx. 40% per year, which will lead, in turn, to a tenfold increase in this volume occurring every 6–7 years. It is estimated that the total online traffic will amount to 100Tb/s close to 2020. Conceptual works covering the concept of implementing fibre-optic communication speak of a traffic volume of 1Pb/s. According to IDC[5] – even 35 zettabytes (i.e. 35 billion terabytes) of data will be stored by 2020, which will be a 44-fold increase in the amount of information compared to 2009.

### 1.1. A rapid increase in the amount of data (the phenomenon of the so-called „*Big Data*")

Big Data techniques make it possible to obtain data and information concerning various areas of operations, entities and events from different data sources, taking advantage of various data structures or containing non-organized data from different periods of time. These techniques are essential for analyses of the outcomes of business operations for all market entities and the occurring trends in changes in the markets of one's interest, analyses of particular markets, and analyses of the needs of potential clients. Big Data techniques are among the basic measures applied in the field of digital transformation, and it will also be possible to use them for analysis of one's performance compared to the competition, or to analyse the needs and expectations of clients in the transport sector.

We can also see BI (*Business Intelligence*) systems – supporting strategic and tactical decision-making aided by analyses of organization-internal processes – as well as CI *(Competitive Intelligence)* systems – offering in-depth analyses of the competitive environment – being implemented. CI solutions analyse information covering macroeconomic (e.g. GDP) and market (e.g. prices of raw materials or power and values of investment projects) data, but also data related to the competition (e.g. a view on the effectiveness of company-internal processes) [12].

## 2. IT in transport

The societies of today are dependent on efficient logistics systems defined in broad terms. The dynamics of transport and the collaboration with other institutions and enterprises make it unfitting for transport to fall behind the trends of global development in the area of ICT solutions. Transport should not be a backwater in the area of IT systems if only for the surrounding environment and the collaboration with this environment. A common feature of IT systems, especially of systems designed for transport-related purposes, is that they are used to manage huge areas, and therefore have to be connected to data transmission networks. According to the author, a data transmission network is one of the most fundamental components of modern-day IT systems. Transport is one of the elements of a logistics chain composed of:

- a multi-purpose logistics service system,
- an integrated ICT system.

In order for a logistics centre to operate properly, these systems need to be able to exchange up-to-date information used to create messages. These messages serve the following four main functions:

1) information function,
2) decision-making function,
3) control function,
4) consumption function.

The above-mentioned systems (i.e. logistics and ICT systems) are increasingly interconnected and tend to develop on a continuous basis. At present, the field of logistics sees an ongoing search for a system solution that will make it possible to improve process efficiency and to develop logistics solutions, while maintaining an economic, social and environmental balance at the same time. Such solutions should minimize the current problems common to the area of logistics, i.e.

- inefficient utilization of the available loading space,
- empty runs,
- non-standard cargo dimensions,
- unwillingness to cooperate among logistics operators,
- traffic disruptions (congestions, emission of $CO_2$),
- storage of goods in the wrong places and inappropriate amounts,
- problems with demand forecasting – a part of production volume will never be sold or used,
- problems with supplying goods to city centres,
- no automation in the organization of transportation processes (low level of application of the same standards in small and medium enterprises) [8].

The so-called „Physical Internet"[6] is supposed to be the solution to the said issues. Physical Internet (PI) is a combined communication infrastructure, with use

[5] IDC (*International Data Corporation*) is the world's leading provider of market data, consulting services and solutions for the ICT and consumer technology sector.

[6] Physical Internet – a system of global supply networks that brings together local supply networks (markets), taking advantage of their resources in the following areas: transport, storage and manufacture. On account of the systems' similar mechanism of functioning to that of the Internet, Professor Benoit Montreuil (*Professor and Co-Director Supply Chain &Logistics Institute at Georgia Tech*) has named this concept the Physical Internet (*PI*); the symbol of the Physical Internet is the Greek letter π.

of modular standardized load units for transportation purposes, and the exchange of data concerning the occurring logistics processes.

The Physical Internet assumes changes in the properties of distribution network elements and of the processes carried out therein, i.e. a gradual shift from private supply networks to a global open distribution network. Its elements (distribution hubs and warehouses, etc.) will be available to most clients, networks of manufacturers, distributors, logistics service providers, retailers or end users. In a network formed according to the concept of PI, goods and materials will be transported in standard modular secured containers (π-containers and π-transport/storage units) [14]. This will make the storage of transport/storage units belonging to different clients much easier. Containers and transport/storage units will have to feature various types of sensors (of temperature, humidity and shock, etc.) and transmitters (e.g. RFID[7] and GPS[8]) to make it possible to maintain full control throughout the process of transportation [8].

A complete exchange of information between the users of the Physical Internet is required in order to achieve certain desired (economic, social and environmental) effects resulting from the use of PI. The transmitted data will concern shipments, transport- and storage-related needs, the readiness of π-transport / storage units for transport and the available storage space. Application of a PI system will make it possible to optimize the flow of containers in a network thanks to the ability to select routes and places of storage, to combine loads and place them in appropriate warehouses [14].

The purpose of the Physical Internet is to considerably shorten the duration of supply cycles, limit the negative environmental impact and improve the effectiveness of logistics processes at the same time. The idea of the solution is connected with extensive standardization, encompassing mainly collective and transport packaging, and offering conditions in favour of efficient trans-shipment at nodal points upon which a PI system is based. A PI system should come with standard data transmission protocols for all services that are to be provided by means of this system. A PI system optimizes the load flow in a network thanks to the selection of routes, trans-shipment points, load combination points and storage. PI system users work using their autonomous IT systems, and connect to the PI system by means of standardized interfaces.

The Physical Internet will certainly have an impact on the development of an IP ICT system, which should be able to ensure the right quality of data transmitted for transportation-related purposes (appropriate BER, delay, safety and confidentiality of the transmitted data, etc.).

## 3. ICT in transport and logistics

IT systems designed for transport-related and logistics-related purposes include the following stages of the information creation process, managed in the context of ICT as described below:

- information generation (production) – terminals, servers, databases, sensors, RFID systems, alarm systems, monitoring systems and positioning systems,
- information verification (collection) – access networks – wired, wireless, satellite, optical and radio,
- information storage (recording, archiving and saving) – data warehouses, databases, servers, portals, vortals and websites,
- data transfer (transmission) – TCP/IP, LAN, WAN, WLAN, GSM 4G and 5G, Bluetooth, IrDA and WiFi, etc.,
- information processing (modification and transformation) – servers and hosts,
- making information available (sharing) – portals, vortals, screens, information display boards, signs, pictograms and websites,
- information interpretation (translation into the user's language) – transparency of networks of data transmission for different types of IT protocols, e.g. CRM (*Customer relationship management)*, ERP (*Enterprise resource planning*), Cloud Computing and SaaS (*Software as a Service*), etc.,
- information utilization (use) – in other systems, e.g. HR management and finance-accounting systems, etc.

The increasingly present Internet of Things (applications) *(IoT),* which will enable better use of IT and ICT solutions by offering new functions and features, increasing the level of performance and automation, and by improving the rate of data transfer used for the purpose of real-time decision-making, will have a significant impact on the development and management of IT developments.

IoT will be used to manage, collect and transfer data between systems or equipment featuring computers with access to the Internet. It is a solution that makes it possible to create intelligent rolling stock and intelligent transport systems (ITS), and which will

[7] RFID – Radio-frequency identification.

[8] GPS – Global Positioning System.

also act as a means of support for railway companies in the area of transport service provision. IoT is also a solution supporting and optimizing the acquisition of up-to-date data, ensuring a lower level of errors. Without the implementation of innovative solutions in transport enterprises, it will soon be difficult to see their economic performance improve, which will make it hard for them to survive in the market.

IoT is an area where many innovations are born and developed; innovations that may not only aid transport enterprises but also support such enterprises' clients and their business.

## 4. ICT in rail transport

Railway transport takes advantage of IT solutions for the following purposes:

1. **Management**
   Railway companies should not fall behind in terms of the management systems they use with regard to their clients, and this requires the application of IT-aided management methods, adapted to the specific profiles and requirements of particular companies, e.g. infrastructure operators (PKP PLK), railway traffic operators, e.g. Intercity (IC) and Przewozy Regionalne, and other companies, e.g. Energetyka PKP, etc.
2. **Instructing**
   Instructing includes all types of dispatcher centres, e.g. traffic dispatcher centres, power supply network dispatcher centres and supervision of telecommunication network systems, e.g. GSM-R, etc.
3. **Control**
   Controlling ERTMS[9], DSAT[10], air conditioning and lighting systems, etc.
4. **Monitoring of railway areas**
   IT systems used to monitor railway areas, i.e. hump yards, trans-shipment points and Schengen border crossing zones, etc., supporting and ensuring safety to people (travellers, state services staff working in e.g. borderland areas), goods (warehouses and storage facilities, hazardous materials and agents), railway infrastructure, rolling stock and means of internal transport (e.g. trolleys, carts and overhead cranes, etc.).

## 5. For railway clients and passengers

The IT-related needs of railway clients include the monitoring of selected railway areas (e.g. car parks for travellers), travel safety (before, during and after the journey), broadband access to the Internet, dynamic timetable systems, mobile information and ticket sales, and monitoring of freight transport, etc.

In order to fulfil all the requirements of IT systems implemented for railway-related needs, it is necessary to have an ICT network that would act as a base for all IT systems applied in the railway industry.

At present, PKP PLK is managing the construction process of a fibre-optic network to support the use of GSM-R, which is a component of ERTMS. The GSM-R network will replace the currently used – and rather technically outdated – analogue simplex VHF 150MHz radio communication network. The GSM-R network will cover around 18,000 km of railway lines. Apart from the „voice" service, the GSM-R network will also offer a data transmission service, which is an essential feature of modern railway traffic control systems (ERTMS).

The wired part of the GSM-R system, connecting its stationary elements (base stations – BTS, base station controllers – BSC, and central stations – MSC) should be, for safety reasons, formed using separate optical fibres, which will have appropriate teletransmission systems (e.g. SDH and Ethernet) implemented. Other IT systems required for operations pursued by railway companies should take advantage of other optical fibres, found in the same cable as the fibres used by GSM-R.

As – from a railway point of view – an infrastructure based on fibre-optic technology offers unlimited data flow capacity (multi-fibre fibre-optic cables, the application of DWDM systems[11] and high data flow capacities of fibres thanks to the application of „*Optical cross connect*"[12] systems therein, where every $\lambda$ may transmit huge amounts of data – at present, $\lambda$ = 100 Gbps, soon, $\lambda$ = 400 Gbps, and even $\lambda$ = 1 Tbps in the future), then taking only the economic aspect into account, such a network should be used with all railway IT systems.

Fibre-optic technology is developing not only for backbone network but also for access network ap-

[9] ERTMS – European Rail Traffic Management System.

[10] DSAT – stock break-down detection system.

[11] DWDM – Dense Wavelength Division Multiplexing, multiplexing of many optical signals in one fibre-optic cable, involving assigning a different light wave length (frequency) – $\lambda$ – to each signal.

[12] *Optical cross connect* – Backbone network – light paths are a dynamic composition of waves of different lengths ($\lambda$), passing through fibre-optic cables connecting the lambda switching equipment. For the purpose of formation of a light path, signalling will be managed via the MPLS (*Multiprotocol Label Switching*) protocol and adapted protocols such as RSVP (*Resource reservation Protocol*), RSVP – TE (*Traffic Engineering*). The flexibility of MPLS and RSVP will make it possible to offer unique services, such as virtual private optical networks, and to offer ISO/OSI model VPN layer 2 and 3 (*p2p*, *m2m*) services at the same time.

plication purposes. Even now, we can see so-called PON2 *(Passive optical network)* networks available, able to transmit lambdas of 100 Gbps to the subscriber [15] – the plan is to have the third PON network generation, PON3, available by 2020, offering a 250 Gbps data transfer speed.

The development of wireless networks appears to be equally fast. At present, we already have a roadmap outlining the time horizon for implementation of the 5G system for public utility networks (pilot implementations of 5G are being carried out by telecom service providers in various countries – including Poland). The preliminary key requirements for the 5G system, together with some suggested target values, are as follows:

- equipment operating environment involving a network of the density of 200,000 connections/km$^2$,
- data flow capacity of 0.1 to 1 Gbps, as necessary,
- data transmission speed of 10 to 100 Gbps,
- data transmission delay reduced even to 1ms, depending on the requirements,
- long equipment uptime without the need to recharge its batteries (battery lifespan 100 times greater than in the systems currently used),
- greater reliability and accessibility compared to the systems in use at present,
- mobile equipment mobility of up to 500 km/h,
- a greater number of offered services and applications than the systems currently in use.

The plan is for the 5G system to work with licensed frequency bands (2G, 3G and 4G), non-licensed bands (2.4 GHz and 5 GHz), and new frequency bands above 6 GHz.

The question is, though, whether European railways actually need data transmission based on parameters offered by the 5G system.

The UIC environment speaks of various variants of the new generation of wireless communication networks to be used in the railway transport industry. Different arguments are taken into consideration:

1. Implementation of the 5G technology in wireless railway communication would surely address all the railway-related needs successfully.
2. Some experts believe that railway infrastructure is part of the state critical infrastructure, and there should be a common network for all so-called „*blue light*" services (police, fire brigade and emergency ambulance service, etc.) and economic sectors ensuring the survival of people in critical situations, such as wide-scale power outages, heating network failures, rail water supply network failures, no fuel supplies, network-related transport risks and ITS[13], etc.), developed as part of a PPRD *(Public Protection and Disaster Relief)* system.
3. GSM-R networks should develop through the introduction of a packet transmission service (GPRS) and IP networks for ETCS-related applications, and GSM-R and VoIP (*Voice over Internet Protocol*) are enough to handle voice message transmission for railway-related purposes.
4. Another option involves taking advantage of satellite communication for railway purposes (some experts say that this "better than nothing" type of communication system may, given the occurring delays, be applied only with peripheral railway lines).
5. In January 2014, UIC launched a programme named the „Future Railway Mobile Communication System (FRMCS)". The decisions concerning the future system will be made this year, and the system itself should be made ready for implementation after 2022.

The Polish ICT railway network should be in line with the development of ICT railway networks in Europe in terms of both wired and wireless (frequency band and technology) aspects in order to be compatible with the ICT systems used by other railway management entities.

The development of rail transport, of the services in public ICT networks, and of the IT systems used in the railway environment, will „force" the implementation of next-generation ICT networks in particular railway management entities, as it is hard to imagine train passengers not having access to broadband Internet within the next few years to come.

An ICT network used in rail transport, which is organically compatible with many different IT systems and compliant with European trends and standards at the same time, should also be adaptable to the extent that it is able to meet the requirements of compatibility (integration) with networks used in economic sectors ensuring the survival of people in critical situations, such as power outages, road transport incidents and fuel market collapse, etc. In addition, the IT systems developed for rail transport purposes should be compatible with ICT railway networks featuring different mechanisms of data transmission because of their evolutionary (not 'revolutionary') development and the multitude of IT systems utilized in the transportation sector.

These networks will soon be based on a network operating on the basis of TCP/IP protocols, the so-

[13] Intelligent Transportation Systems – systems that form a broad spectrum of different technological (telecommunication, IT, automation and measurement) solutions and management methods applied in the area of transport to protect the life of traffic participants, improve the effectiveness of transportation systems and protect the natural environment assets. Source: ITS Polska.

called „Internet of Things" (*IoT*) network. This network is most likely to integrate and work with different IT systems and networks. This network will ensure communication between cloud-based data centres and users with any computer or mobile device connected to service servers through broadband Internet at their disposal. This is especially important in the railway industry because of the nature of railway operations, which cover whole areas where services are available, and involve the movement of means of transport, people and goods.

## 6. The problem of broadband networks in the PKP Group

The problem of broadband networks and services in the PKP Group appears to be marginalized, i.e. there are no steps being taken within the group itself to address the issue, nor are there any research centres in Poland working on solutions that would make it possible to implement broadband services in the Polish railway industry in the near future. A number of diagnostic-development programmes for the Polish railway industry have been developed, but none of them address the said problem [1].

The long-standing policy of eliminating telecommunication solutions from the Polish railway sector has led to a situation where nobody deals with the implementation of new solutions fuelled by technical advancement or new ICT services for Polish railway lines. This will almost certainly result in Polish railway operators being unable to compete in the railway market and, therefore, in the marginalization of rail transport in Poland. It is, in general, against the relevant EU policy, which aims to equalize the opportunities available to both rail and road transport. At the same time, one may claim that the result of the situation in question is that there are no telecommunication experts who could work out appropriate concepts for implementing broadband services that could address the needs of the Polish railway industry.

## 7. Suggested directions of development of ICT in the railway industry

In the near future, PKP PLK will become the owner of around 18,000 km of fibre-optic cables necessary to establish a GSM-R network designed to be used with ERTMS. At the same time, GSM-R will replace the outdated analogue system of 150MHz band radio communication used so far by PKP.

Experience shows that fibre-optic cables can be used in a railway environment and maintain their original performance for many years. The first fibre-optic lines used in Poland in the railway industry were laid in the first half of the 1990s, and are in use to this day. That's why it is necessary to form a fibre-optic network in a way that is able to satisfy the teletransmission needs of all railway companies in the perspective of several dozen years. This means that it is important to take immediate measures to define a long-term strategy for the development of Polish rail transport for, say, a time perspective to the year 2050.

Rail transport in Poland should keep up with the development of rail transport in Europe, but also of other land transport sectors. One of the preconditions for such development to be effective is to have modern ICT systems (Cloud Computing, Big Data and IoT, etc.) at one's disposal. This will allow various railway companies to work with each other and with foreign partners alike, to make them able to offer new IT services to their clients, and to help them address their transport-related needs better. In the long run, it will be possible to offer IT services to private entities, involving e.g. multi-modal and road transport, create an Internet network for land transport (unmanned rail vehicles and autonomous cars), and then establish an ICT network to be used with the Physical Internet (PI).

In order to make rail transport safe for the transported passengers and goods, there should be appropriate systems (e.g. ERTMS composed of ETCS and GSM-R) established on physically isolated optical fibres, where data transmission is particularly protected against e.g. unauthorized access to the said systems. To summarize, it can be concluded that:

- railway companies have to work with their environment, i.e. with other railway companies, with railway clients, with other transport sectors and with state and local government authorities, etc.
- railway companies will need appropriate IT systems to be able to collaborate with their environment, and that's why the railway industry should keep on developing and modernizing the ICT systems it takes advantage of.

An ICT network formed in such a way should be managed by an expert, appropriately qualified railway entity. Such an entity could be Spółka Teleinformatyczna (telecommunication and information technologies) established within PKP S.A.'s holding company.

## 8. Conclusions

1. It would be reasonable to form an interdisciplinary group to work on the concept of an ICT network to address the needs of rail transport, and to determine the principles of functioning for this area of transport in a Physical Internet (PI) domain.

2. The ICT infrastructure related to railway traffic control defined in broad terms should also be physically isolated from the infrastructure of other railway ICT systems.

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