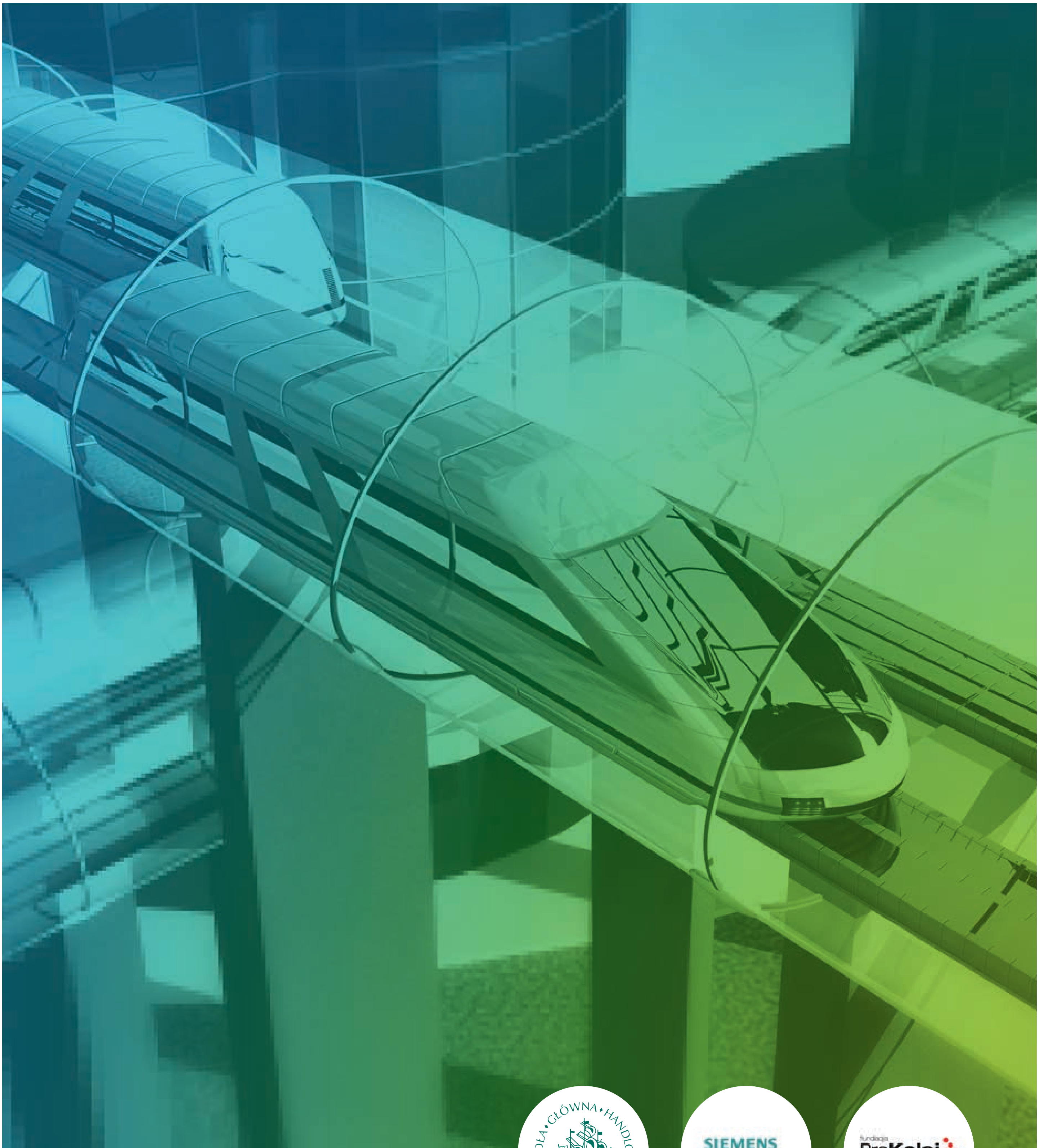

DIGITAL TRANSFORMATION OF RAILWAYS

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CONTENTS

EXECUTIVE SUMMARY

The creation of smart, environment and user-friendly mobility systems is among the high-priority directions in the evolution of transport worldwide. Rail transport is recognised as a vital part of this process. Meanwhile, radical advancement in the business environment, facilitated by ICT technologies, requires the existing business models and strategies adopted by rail operators to be brought up to date. The thorough understanding of the concept of DIGITAL TRANSFORMATION is paramount in the development of rail transport in the New Economy.

Digitalisation, as an ongoing process of a convergence of the physical and virtual worlds, is bound towards cyber-physical systems and is responsible for the innovation and change in multiple sectors of the economy.

THE MAIN TECHNOLOGIES AND SOLUTIONS which have accelerated digital transformation in the railway sector in recent years are:

- Internet of Things (IoT)
- Cloud Computing
- Big Data Analytics (BDA)
- Automation and Robotics.

The adaptation to the new conditions of the digital economy is visibly marked by the emergence of the concept INDUSTRY 4.0 as well as, recently, RAILWAY 4.0 and DIGITAL RAILWAY. Mobile applications, e-ticketing, digital train control, signalling and traffic management, digital platforms for predictive maintenance are THE KEY AREAS OF DIGITALISATION IN THE RAIL SECTOR.

New products and services are becoming an integral part of the operations of railway undertakings, infrastructure managers and manufacturers for the industry. As such they contribute to THE CREATION OF ADDED VALUE FOR MULTIPLE STAKEHOLDERS in public transport initiatives, which facilitates the implementation of new concepts of mobility.

In the past three years, railway companies in different countries have developed their digitalisation programmes. Solutions proposed within such initiatives as the Shift2Rail public-private partnership and UIC Digital Platform promote digital transformation of railways on a European scale.

THE NEW CHALLENGE, MUCH GREATER THAN THE IMPLEMENTATION OF NEW TECHNOLOGIES IN OPERATIONS, IS PRESENTED BY THE CONSOLIDATION OF LATEST DIGITAL TECHNOLOGIES AND BUSINESS PROCESSES BY RAILWAY COMPANIES – EXPRESSED AS DIGITAL TRANSFORMATION.

DIGITAL TRANSFORMATION

DIGITALISATION, in the social-economic context, is understood as a process involving a substantial change of how digital and computer-based technologies can be used by the society, business entities in different sectors of the economy, and the public administration. Beside **DIGITAL ECONOMY**, other notions pertaining to the new model of economy have been coined. These include: *E-Economy, Network Economy, Mesh Economy, Data Economy, Bit Economy, Access Economy, Platform Economy* and *On-Demand Economy*.

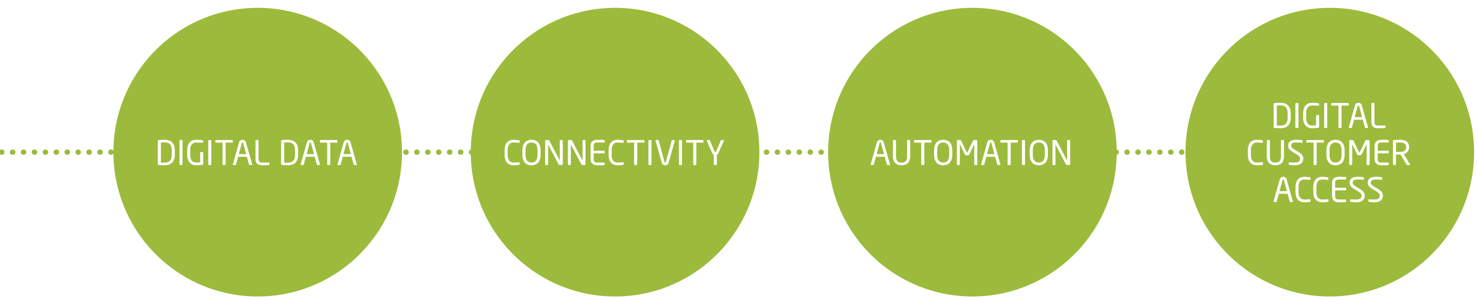
DIGITAL BUSINESS TRANSFORMATION is a special kind of organizational change of the enterprise, sector and entire supply chains through the use of digital technologies and new business models to improve their performance.

Digital transformation has impact on three major areas of business activity:[1]

- modelling of customer relations, embracing the understanding of customer experience, cross-channel coherence including self service
- operational processes, including the organisation's internal processes and worker enablement, as well as performance management
- the business model understood as the selection of products to offer and markets to serve.

> ***DIGITAL TRANSFORMATION involves a consolidation of digital technologies and a company's business processes which, increasing the value to the company's proposition and its market position causes a digital disruption in the competitors.***

THE FOUR LEVERS OF DIGITAL TRANSFORMATION, as identified by Roland Berger,[2] based on research on key sectors of the German and European economies, are:



The progressing digitalisation effects the tightening of competition between companies using more traditional business models and those embracing the newly-emerged ones, which offer:

- **multi-products/services**
- **connected products**
- **embedded services**
- **shared products/services.**

Products and services are offered via **omni-channels**.

Recently the term **DIGITAL DISRUPTION** has been created, denoting the effect digital technologies and business models have on a company's current value proposition and the resulting market position.[3] This assumes the impact the company has on the competition as a result of the implementation of new business models combined with the emerging technologies.

Business models that have disrupted other, more traditional and verified ways of doing business, called *hyper-disruptive models*, include: *The Subscription, The Freemium, The Free, The Market Place, Access over Ownership, The Experience, The On-Demand, The Ecosystem*. Hyperdisruptors combine different business models, knit together different types of capabilities and deliver customer value in new ways.[4]

Digital economy assumes a conversion of traditional ways of a business's market operations and the emphasis on particular components of the **ADDED VALUE**. Following research by Global Centre for Digital Business Transformation, digital business models can be grouped into three categories:

- **cost value**
- **experience value**
- **platform value,**

with a growing importance of the latter.

KEY FACTORS IN THE CREATION OF ADDED VALUE AND COMPETITIVE ADVANTAGE IN DIGITAL ECONOMY ERA

INDUSTRIAL ERA

- Products
- Value chains (linear)
- Power of controlling supply chain
- Supply-side economies of scale
- Physical assets and capital depreciation
- Diminishing returns
- Market valuations driven by return on assets
- Growth organic or via mergers and acquisitions
- GDP as economic measurement

DIGITAL ECONOMY ERA (INDUSTRY 4.0)

- Platforms
- Ecosystems (non-linear)
- Power of optimizing ecosystems
- Demand-side economies of scale
- Digital assets and innovation capital
- Distribution power law and network effects
- Market valuations driven by ecosystems
- Growth driven by asymmetric and network effects
- New measures, digital density and 'free goods'

Source: Accenture Technology Vision 2016, p. 43.
https://www.accenture.com/pl-pl/insight-technology-trends-2016 (Accessed on 10.01.2018).

INTERNET PLATFORMS offer resources that are dispersed worldwide, thus effecting a reconfiguration, or a configuration in the case of new businesses, of their value chains. These platforms make use of the effects of the building of new models which are based on open ecosystems and create new, virtual added value. This allows for the transfers of competencies between sectors, which in turn, contributes to the creation of new products and services over a short time space. As platforms create value for all stakeholders while using resources that they do not own or control, they can grow much faster than more traditional businesses. While market-leading businesses of the industrial era acted by the principles of supply economies of scale, today's giants turn to demand economies of scale, expressed as **NETWORK EFFECTS**. These benefits are not equal to the price advantage or brand value. Platforms derive much of their value from the communities they serve.[5]

KEY TECHNOLOGIES


GB GSM-R
Connected PTT
All Trains in Area

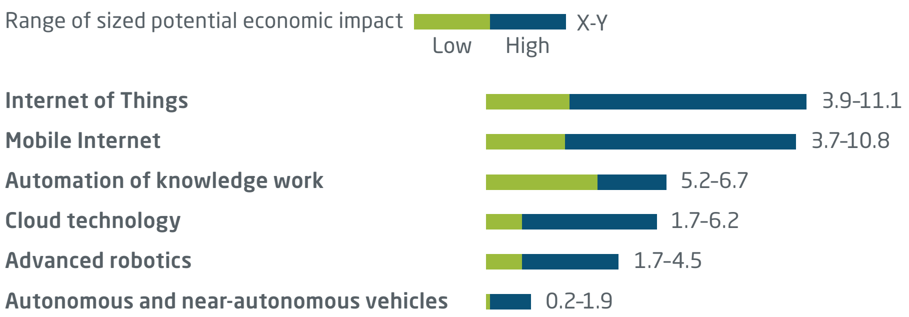
The key driving force of digitalisation is the development of **INTERNET** which since the 1990s has become available not only to the limited number of corporate, but also to individual private users. Global Digital Snapshot reports that in January 2018 there were over 4 billion internet users worldwide, which represents ca. 53% of the world's population. Development of the web-based technologies has substantially changed the communication patterns between businesses, organizations, communities, and individuals. Social media, as interactive Web 2.0 Internet-based applications, have become a dominant tool for information sharing. The number of social media users who drive the development of other sectors has reached 3.2 billion.

Hyperconnectivity facilitates the growth of multi-lateral interaction patterns, such as: people-to-people (P2P), people-to-machine (P2M), as well as fully automated data exchange between machines (M2M). Cisco defines the beginning of the era of **INTERNET OF THINGS (IoT)** as the time period when the devices connected to the internet outnumbered the world's population, which was reported in 2009. Understood as an ecosystem, Internet of Things, rather than expanding the usability of the internet, it introduces new services using P2M and M2M interactions.

IoT is growing rapidly, with 127 new devices connecting to the internet every second as of the beginning of 2018. Although many new applications, including smart-home systems and connected cars, target consumers, others help companies optimize operations, ranging from manufacturing to customer segmentation.[6] IoT will be the largest source of value of all disruptive technologies, ahead of mobile Internet, knowledge-work automation, cloud computing, and advanced robotics. McKinsey Global Institute estimates that linking the physical and digital worlds could generate up to $11.1 trillion a year in economic value by 2025.[7] IoT will also drive new business models.

Meanwhile, for IoT to be able to render business value, it is necessary to adopt the appropriate approach to data analysis and to implement automation. IoT is among the main facilitators of transformation processes as per EU's Digital Single Market Strategy of 2016.

ECONOMIC IMPACT OF DISRUPTIVE TECHNOLOGIES BY 2025 ($ trillions per year)

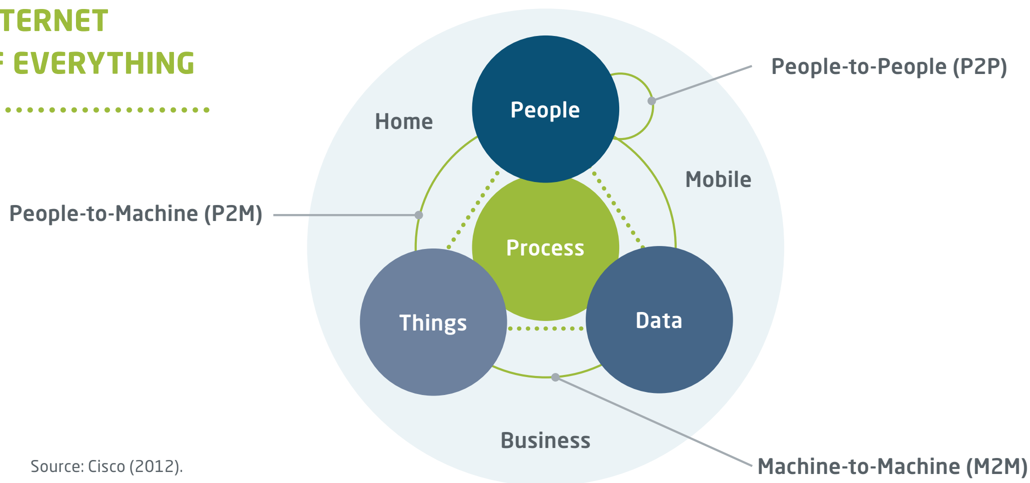


Source: McKinsey Global Institute analysis (2017).

2014 saw the so-called **MOBILE REVOLUTION**, as the users of internet via mobile devices outnumbered those gaining access via desktop computers. As estimated, the number of mobile devices in early 2018 was 5,135 billion. The number of smartphone and tablet users seeking and sharing information, making purchases and bank payments on line is continually growing, with an average user consuming 2.3 GB of data monthly. Overall, mobile devices generate ca. 60% of the volume of internet traffic.

Since 2015, wearable devices and beacons – small radio wave transmitters that communicate with smartphones – have been available to the individual buyer. **INTERNET OF EVERYTHING** is a new concept, denoting a network of objects, data, processes and humans continually connected to the internet using such devices as computers, tablets and smartphones, but also using software that supports continuous connectivity, as well as sensors, both in individual households and in the industrial context. In turn, ABB uses the term *Internet of Things, Services and People* (IoTSP). The next stage in the evolution of the concept of IoT will probably be *Internet of Robotic Things* (IoRT).[8]

INTERNET OF EVERYTHING



Source: Cisco (2012).

THE EVOLUTION OF THE INTERNET

AT THE CONNECTIVITY AND INFRASTRUCTURE LEVEL	AT THE CONTENT AND SERVICE LEVEL
• The Internet of Computers (IoC) • The Internet of Devices (IoD) • The Internet of Services (IoS) • The Internet of Things (IoT) • The Industrial Internet of Things (IIoT) • The Internet of Everything (IoE) • Internet of Things, Services and People (IoTSP) • The Internet of Robotic Things (IoRT) • The Internet of Emotional Things (IoET)	• **Web 1.0**: The simple web - reading only • **Web 2.0**: The social and co-created web - reading and writing • **Web 3.0**: The semantic and smart web - it combines human and increasingly available machine intelligence to make information more relevant, timely and accessible • **Web 4.0**: The mobile, machine and objective web - a mobile space where users and real and virtual objects are integrated together to create value • **Web 5.0**: The sensory-emotive web - where people are able to move the web from an emotionally flat environment to a space of rich interactions

Source: adapted from: Raj, P., Raman, A.C. (2017). The Internet of Things. Enabling Technologies, Platforms, and Use Cases, CRC Press, p. 9; Kambil, A. (2008). What is your Web 5.0 Strategy? *Journal of Business Strategy*, Vol. 29, Issue 6.

The **CLOUD COMPUTING**, a mechanism using diffused data processing whereby services are provided by external entities and are available at any moment and rescale according to demand, is expected to facilitate data processing. This alternative to own data centres requires no additional investment in own IT infrastructure.

The three types of cloud computing are: private, public and hybrid. To meet all users' expectations, a range of cloud computing models are available, including, crucially:[9]

- **Software as a Service (SaaS)**. This model allows for the rental services offered by applications made by the supplier of the solution, which can be consumed by users. This service not only offers hardware and software platforms on which we can deploy our own applications, but also provides ready to use applications, hosted by the operator of each solution.
- **Platform as a Service (PaaS)**. This model offers a higher degree of superiority that provides IAAS: it provides a hardware platform, operating system software and all associated servers: application servers, databases, etc. Therefore, it is a complete software platform on which it is possible to develop one's own applications or migrate.
- **Infrastructure as a Service (IaaS)**. This package offers a scalable computing capacity. Its interface level is about the operating system. It is then possible to use its own way by installing server software, database, and applications.

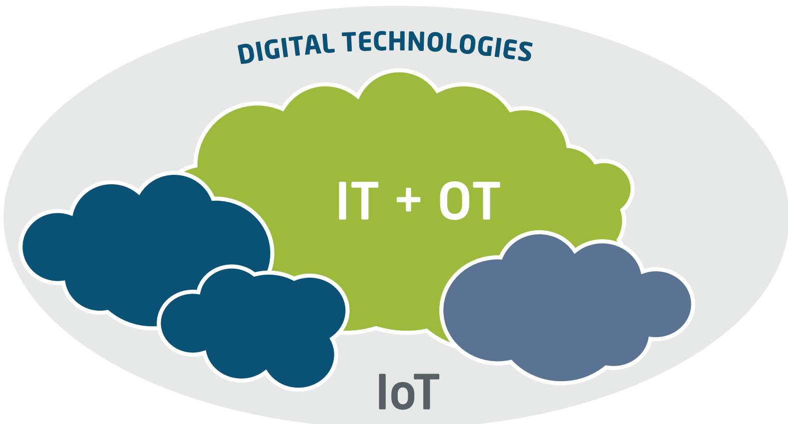
One other available model is **Anything as a Service (XaaS)**, which employs cloud computing combined with one of the other models or a blend thereof.

The rocketing volume of created, transmitted and stored data entails an increase in the demand for advanced analytical tools (data analysis tools) as well as **Big Data as a Service (BdaaS)**. Following Gartner, a growing number of providers offer a *device mesh*, which is an ever-expanding set of end points used to provide access to applications and information or to interact with others, for keeping in touch with social communities, governments and businesses.

The combined IT technologies, operational technologies (OT) and IoT have lain ground for the emergence of the concepts **INDUSTRY 4.0** and **INDUSTRIAL INTERNET OF THINGS (IIoT)**, which assume that automated production based on real-time data exchange with the use of a range of technologies, will render a reduction of overall operational costs, improve performance and the capacity to offer advanced products and services, while still observing the behaviour and preferences of their consumers.

The implementation of the concept of *Industrial Internet of Things* requires a consolidation of IT systems and OT systems. The former are used to manage business processes and customer relations and facilitate key decision making, while the latter are responsible for monitoring automated production, facilitate controls and the relevant processes. IT and OT use separate software and are built to address different requirements, industry-related standards as well as they differ in the way they operate.

CONSOLIDATING IT SYSTEMS AND PRODUCTION SYSTEMS (OT)



DIGITALISATION IN RAIL TRANSPORT

Digitalisation entails a number of future challenges in terms of the ability to meet the needs of the economy and the society. To address these challenges, the rail industry has developed across all areas of its activity: from manufacturing to infrastructure management, to transport operations.

TICT technologies have been employed by railways since the 1970s. For example, digital freight and passenger car codes, introduced almost 50 years ago, are still in use today. The same system was only introduced for rail traction vehicles after 2010. In the following stage of rail digitalisation, computer-aided design of rolling stock became a common practice, as it corrected the weight distribution while improving durability of the vehicles. The ongoing evolution of design tools has also allowed for improvements in the design of powertrains and all auxiliary systems, making modern vehicles more energy-efficient. Digital data recorders, digital steering of particular subsystems as well as of the whole vehicle makes remote monitoring and predictive maintenance possible, substantially improving the rolling stock availability through the reduction of number of defects. However, a real breakthrough in digitalising maintenance is only envisaged to follow, when a growing number of systems with be interlinked not only within a single vehicle, but also within the infrastructure and the suprastructure, the whole rail ecosystems.

A ROADMAP FOR DIGITAL RAILWAYS

A Roadmap for Digital Railways published in March 2016 in collaboration between CER, CIT, EIM and UIC specifies that the main areas of deployment of digital technologies in rail transport are:[10]

- offering connected railways by providing reliable connectivity for safe, efficient and attractive railways
- enhancing customer experience by offering better and added value for customers
- increasing capacity by enhancing reliability, efficiency and performance of railways
- boosting rail competitiveness by making the most of transport data.

In November 2017, CER together with EIM, ERFA, UIP, UITP and UNIFE signed the Joint Rail Sector Declaration that reaffirms the continued provision of products and services using digital technologies for the benefit of people and to make contributions to the Digital Single Market. They have called on the European Commission to uphold digitalisation as one of its key priorities and to ensure that the political importance of the topic is reflected in the funding commitments in the next Multi-Annual Financial Framework.[11]

In this section, the most current examples of digitalisation in rail transport are presented.

1. CONNECTED COMMUTER: DIGITAL SERVICES FOR PASSENGERS

In the last five years, European railways have made most significant improvements in modelling a transparent communication with the passengers, evidenced by:

- more informative and user-friendly websites
- mobile applications offering real-time information about vehicles in motion and allowing for ticket purchase and issue and other functionalities
- onboard infotainment services
- dynamic passenger and timetable information implemented at stations and stops.

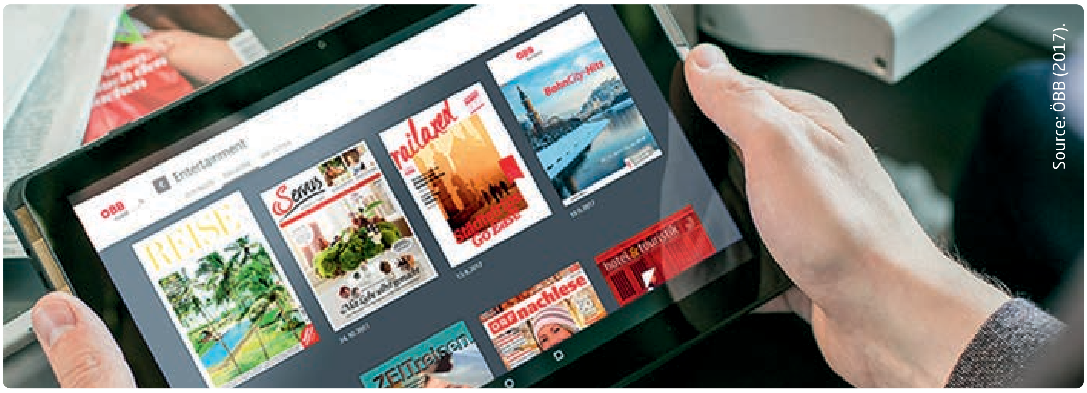
A good example of a mobile application whose basic functionality has been enriched by adding station maps, commercial area listings as well as other services is *ADIF on your mobile* launched by the Spanish infrastructure manager.

ADIF ON YOUR MOBILE APPLICATION

Source: ADIF (2016).

A number of rail operators have launched internet multimedia portals available to passengers on board. In Austria, ÖBB uses the catchy *railaxed* slogan to attract passengers to its *Railnet service*. The service and infotainment on Railjet trains include:

- travel information about the train, the following stops on the journey including real-time connections and an interactive map with live location and speed of the train
- a collection of attractive ÖBB videos (ÖBB TV)
- internet connection via the train's own WI-FI network
- the most recent editions of over 20 regional, national and international newspapers
- over 70 magazines, from economics and sports to fashion and cooking
- ORF TVthek channel
- online platform for classical music with playlists updated monthly (fidelio).



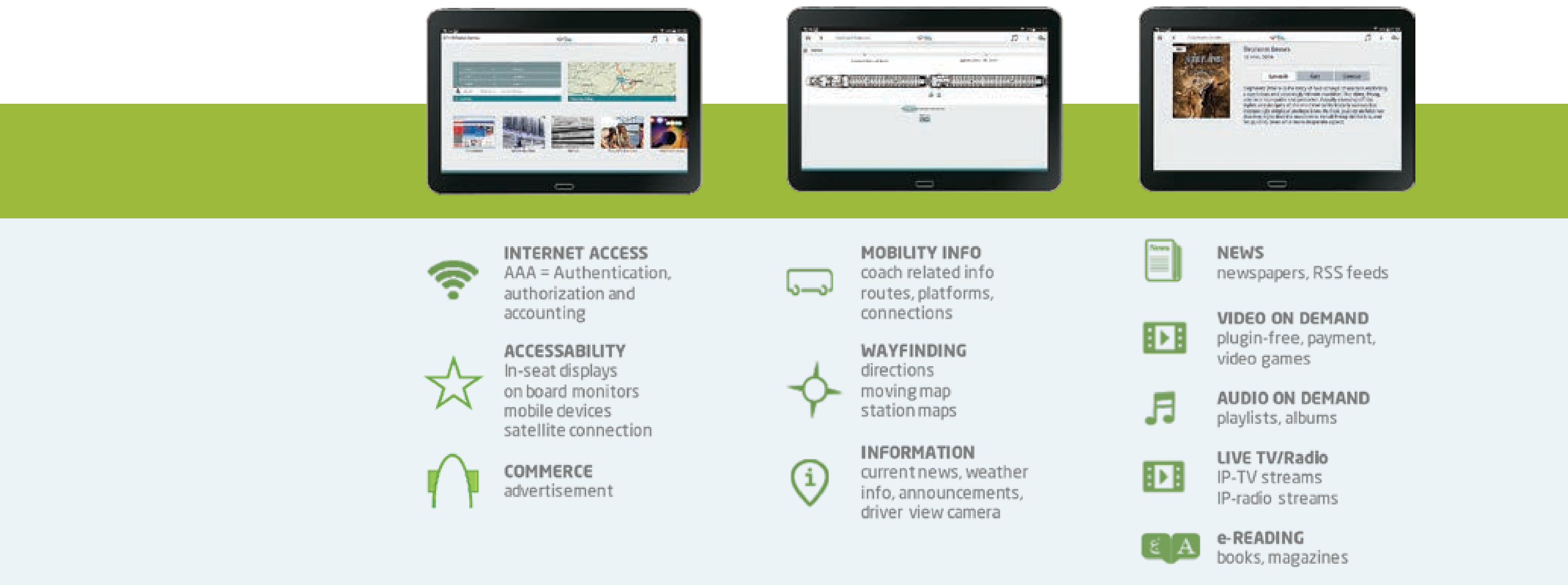
Source: ÖBB (2017).

In Germany, passengers can access the internet at over 135 stations, in DB Lounges and on board ICE trains. The entire ICE fleet of DB Long Distance is equipped with fast, multi-provider WiFi technology. Passengers can use WiFi free of charge in both first-class and second-class coaches. It is also available on all ICE international trains to France, within the Netherlands and to Austria. The free ICE Portal offers an overview of up-to-date information on journey and connecting trains, as well as a wide variety of audiobooks and games, books, films, the news section, daily newspapers, travel & discover, and Kids' World section. No-limit free internet access is provided in first class and a basic internet service in second class that allows passengers to network and communicate, send and receive e-mails, and stay up to date with social media.

In Russia, since October 2016 business and first class passengers onboard high-speed SAPSAN train service connecting Moscow to Saint Petersburg can access the internet and a portal with films, music, audiobooks and magazines. Additionally, the portal offers information about cultural events in both cities, a virtual tour of the train, a range of online courses and information about railways.

In Turkey, passengers onboard the high-speed Siemens Velaro D trains between Ankara – Konya and Ankara – Istanbul can access an internet, passenger assistance and entertainment services, called *AlwaysConnected*. In all of the mentioned cases, infotainment services (paid or free) were first offered to passengers in higher classes, followed by economy class.

SIEMENS VELARO TRAINS OFFERING *DIGITAL ALWAYS CONNECTED* SERVICE



Source: Siemens AG (2017).

There are a number of challenges to connectivity whilst on a train: the metal body of the train weakens the signal, multiple users on the same train reduce the capacity of the network, phone towers flash past and tunnels block the signals. Researchers at Siemens Corporate Technology in Vienna have now succeeded in solving the problem of low mobile internet signal by means of a technique known as frequency-selective coating of window panes. These panes are provided with an electrically conductive, transparent layer consisting of metals or metal oxides. The metallic coating of the window is vaporized along lines in a special structure by a laser. This enables radio signals in certain frequency ranges to pass through unobstructed, while radio signals at a different frequency are attenuated. An innovative frequency-selective window coating from Siemens is improving mobile radio reception in passenger trains. Passengers are enthusiastic about the resulting signal quality, which is up to 50 times stronger. Measurements based on a modified Austrian Railways Railjet vehicle have shown that the length of time during which good 4G reception is available increases by 33%.

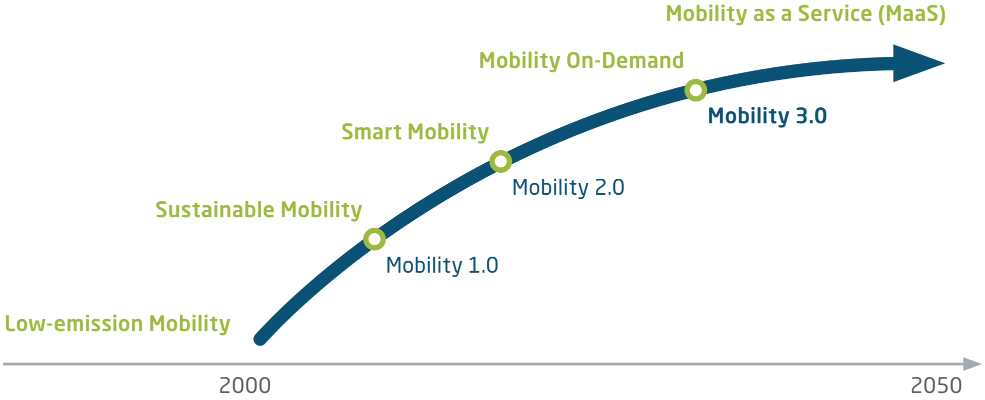
Test subjects gave the innovation a high 'coolness factor' rating and did not notice any impairment in visibility as a result of the window coating either by day or at night. Thanks to this solution it is even possible to achieve improved energy efficiency in some cases, which makes for a more pleasant environment for passengers. The innovative train windows will be used for the first time in the trains of the Rhine-Ruhr-Express (RRX) system, which will begin operating in the Rhein-Ruhr region at the end of 2018. This solution will bring significant savings for railway operators. The windows will need no maintenance over decades of service. Railway operators will profit from lower acquisition and maintenance costs.

2. MAAS: TOWARDS INTERMODAL URBAN MOBILITY

As a result of the process of digitalisation of the economy and society it is becoming necessary to manage one's own time effectively, living in two worlds, the real one and the virtual one, simultaneously. This is made possible by such modern mobile devices as netbooks, tablets, smartphones, voice and video devices for communication between humans and digital systems (Amazon Echo, Amazon Echo Look), that have created **VIRTUAL MOBILITY**. A new personality type has been named *homo mobilis*; it typically features a new understanding of the idea of freedom and the comfort of living, *cybermentality*, the need to be online continually, the need to have continuous internet access and to communicate with others using social media as well as the need for new, personalised products and services, fully tailored to one's values, life style, emotions and personal pursuits.

The terms *nanosecond culture* as well as *always-on mobile* have been used to describe the expectation to be able to access products and services immediately and on demand. Future concepts of mobility, such as: *Mobility on Demand*, *Any Time Mobility*, *Networked Mobility*, are expected to address these needs. Meanwhile, concepts of the evolution of urban mobility that have emerged in the last five years are linked to the evolution of the concept of *Smart City*.[12] The so-called *Smart Mobility* is marked by the orientation to optimal use of the resources across different modes of transport, ensuring intermodality. In *Mobility On-Demand* users are only charged for the functionality that they actually use (*pay-as-you-use, pay-as-you-go*). From the user's perspective, these services mean an improvement of the flexibility and the use of resources according to the actual requirements regardless of the user's location.

THE EVOLUTION OF THE CONCEPT OF URBAN MOBILITY IN THE 21ST CENTURY



Source: Pieriegud, J. (2017).

Each of the new mobility models is connected, meaning that is provides instant access to the internet and ICT systems that offer real-time journey information, to plan onward journey, make reservations and purchase tickets. Such solutions, based on electronic platforms and applications, are called **MOBILITY AS A SERVICE (MAAS)**. It analyses a number of possible journey scenarios, using different modes and means of transport: public and private, it offers booking and ticketing services and it provides for access to locations on route that are important for the traveller, at the same time monitoring the traffic, road works, incidents and accidents on line. This application is available online through mobile devices and it allows for the selection of the mode of transport, also available in real time, following the traveller's preferences, such as: the cost, the time, or carbon footprint left.

The new Deutsche Bahn's *Multimodal Full-Service Mobility Platform 4.0* will consolidate and interlink the existing mobile applications:

- **DB Navigator** – an application is not only the fastest growing booking channel, but now also offers almost all imaginable services around rail travel. Mobile booking, real-time information with current departure and arrival times, delay alert – the DB Navigator accompanies rail customers digitally along their journey and is one of the most frequently installed apps in Germany. In 2017 about 15 million tickets were booked with the app. About four million travel queries are served daily via the DB Navigator. The price finder helps to find the cheapest available fares. Interconnected tickets and regional offers can also be booked. The DB Navigator informs the passenger about the selected connection before, during and after the journey. A door-to-door route planner with GPS tracking and pedestrian navigation as well as suburban, metro, tram and bus connections is integrated. In addition to the real-time information about the trip, the booked mobile phone tickets can also be managed. Since January 2017, the DB Navigator shows the coach numbers, at which platform section the coaches are located and where the 1st and 2nd class are located. Since August 2017, the app also informs about the service on board and the equipment of the train.

- **Call a bike app** – an application used to locate city rental bikes, available across around 50 stations.

- **Finkster app** – it allows to rent cars, including electric cars, available in the so-called car-sharing system at around 1700 stations.

- **Qixxit** – multimodal journey planning tool.

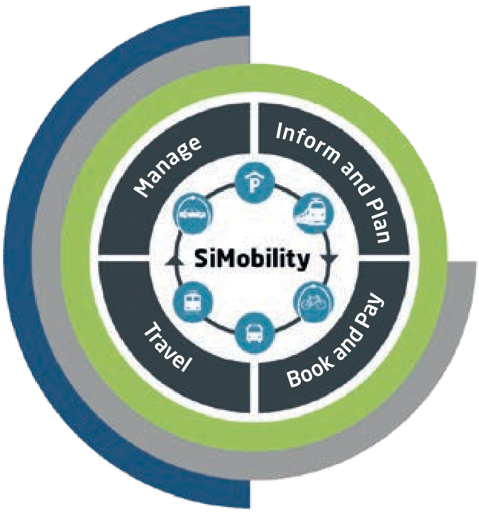
DEUTSCHE BAHN'S MOBILE APPLICATIONS FOR MULTIMODAL JOURNEY PLANNING

Source: Deutsche Bahn AG (2016).

SiMobility is Siemens's collection of digital solutions (SiMobility Connect, SiMobility JustGo and SiMobility Flow) to facilitate journey planning and improve the comfort of travelling before, during and after the journey as well as it offers smart ticketing.

SIMOBILITY SOLUTIONS

SiMobility Connect
B2B platform enabling information and transactions before, along and after the multimodal journey



SiMobility Flow
Proximity-based push information for passenger guidance

Source of usage data for operators

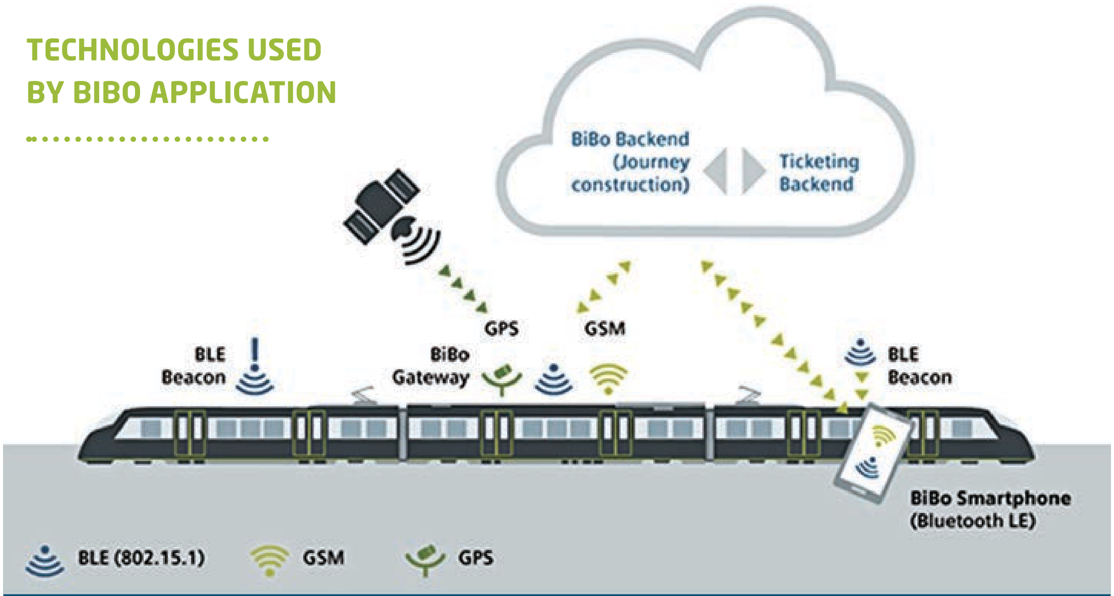
SiMobility JustGo
Hands-free, on-the-go ticketing with BiBo (Be-in/Be-out) and CiBo (Check-in/Be-out) flavors

SiMobility Connect is a B2B platform that enables the integration of the mobility services of various providers into a one-stop portfolio for the user. The platform provides system interfaces for transport operators and mobility service providers as well as integrated processes such as real-time passenger information, multimodal journey planning, booking, ticket purchase and payment – across various transport modes. The means of transport covered can include not only public transport (railways, ferries, cable cars, etc.) but also private transport services such as car sharing, bike sharing and taxis. Constantly updated traffic information can be used to optimize route recommendations in real time.

For local authorities and transport operators, innovative 'as a service' offers and OPEX-based business models lower the financial hurdles and allow those local authorities and operators to expand their mobility offers, which also lays the foundations for *Mobility as a Service* offers. Within the Ertico MaaS Alliance, Siemens is cooperating with European partners in turning this vision of future mobility into reality on the international level.

The main application of **SiMobility JustGo** is **Be-in/Be-out (BiBo) ticketing**. A smartphone with the BiBo app detects installed bluetooth low-energy transmitters (beacons) while the vehicle is running and sends the data to the backend for processing the route taken. Billing takes place on the basis of the route actually travelled, and the cheapest fare may be automatically applied.

TECHNOLOGIES USED BY BIBO APPLICATION



Südostbahn Switzerland (Swiss South Eastern Railways, SOB) are the world's first rail operator to have launched the BiBo tool as a part of Smart Mobility project.

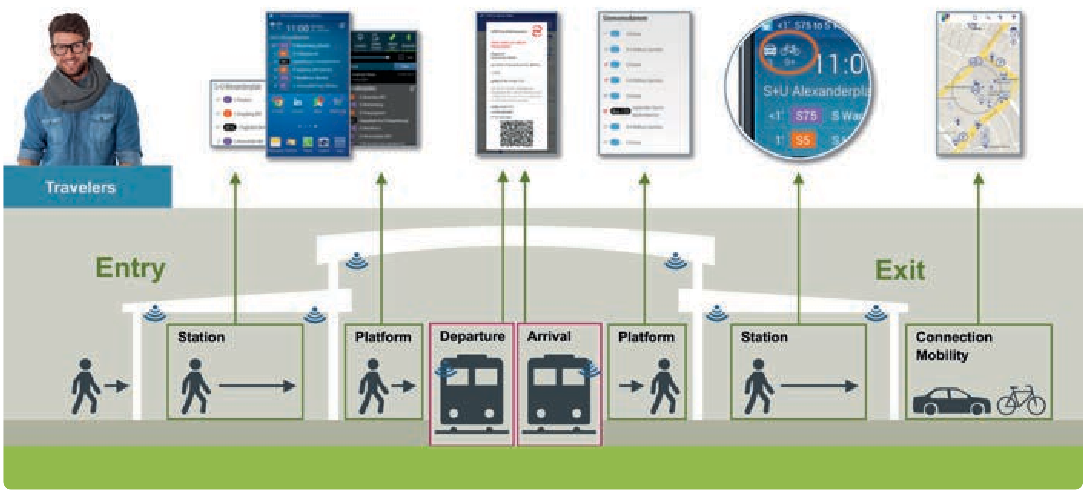
NO CHECK IN | NO TICKET | as a SERVICE | in the CLOUD

Source: Siemens AG (2017).

THE ADVANTAGES OF THE BIBO APPLICATION AS COMPARED WITH TRADITIONAL SOLUTIONS

Source: Siemens AG (2017).

The development of the SiMobility platform and the pioneering of BiBo earned Siemens appreciation for innovativeness in the digital era, expressed by Transport Ticketing Global Award as 2017 Digital Champion.



3. PMAAS: DIGITAL SERVICES FOR ROLLING STOCK PREDICTIVE MAINTENANCE

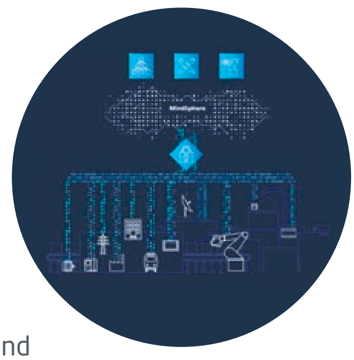
The use of digital data processing is revolutionizing maintenance of infrastructure and rolling stock. Based on millions of data points captured from sensors on critical train components, analytics can detect impending part defects, ensuring maintenance is only done when required, but before a defect occurs. Reliable knowledge of which parts are likely to fail in the near future allows for close to 100% availability, as faults are fixed when units are not currently in service, avoiding breakdowns. This improves the reliability of the system as the typical operational fleet reserves of 5-15% kept as back-up in the event of faults can now be reduced, thus increasing the effective capacity.

By consolidating volumes of maintenance data with business processes and IT systems and using cloud computing, manufacturers of rolling stock are now able to offer a number of new digital services, such as:

- Fault Detection as a Service
- **Predictive Maintenance as a Service (PMaaS)**
- Simulation as a Service.

Siemens has worked on the development of services in predictive maintenance of rolling stock and infrastructure for a number of years. These include:

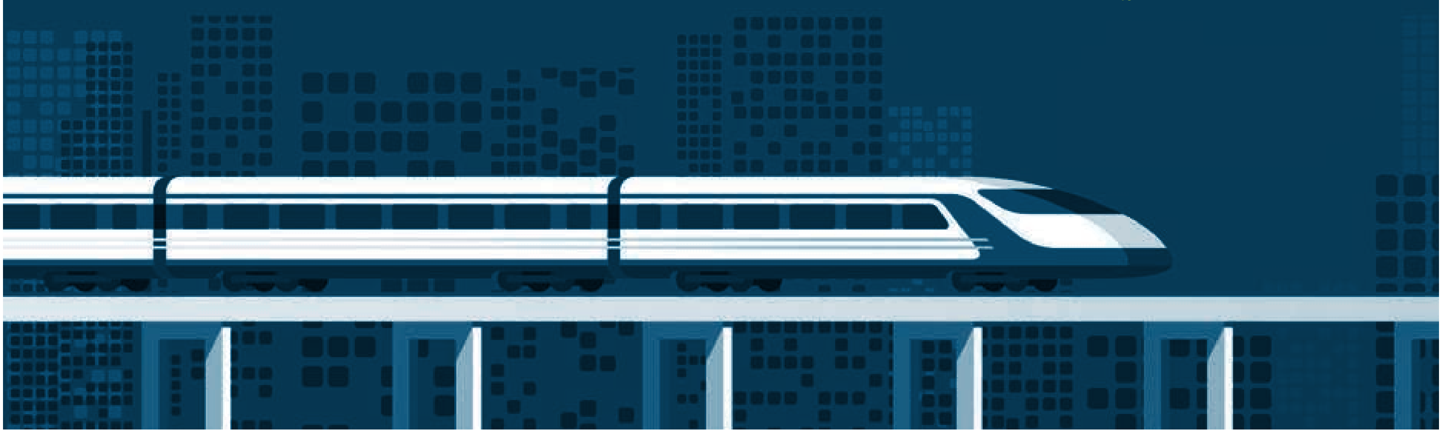
- **remote monitoring of location and condition of all vehicles in real time**
- **remote diagnostics**
- **root cause investigations of faults**
- **automatic data visualization**
- **algorithms for preventive fault analysis.**



The creation of added value of new digital services, such as PMaaS, is has been made possible owing to the cloud-based **RAILIGENT PLATFORM** for the analysis of industrial data and **MindSphere** – the open IoT operating ecosystem that connects a company’s products, systems, and machines. RAILIGENT provides all rail-specific content and tools to monitor, diagnose and improve the performance of rail assets.

For the future of the mobility business, vehicles alone are not the decisive factor. For customers, it is about vehicles' lifetime costs and their efficient use. Success can be achieved only with the help of bundled data from the vehicles, the infrastructure, and the operations. Forecasts of breakdowns and wear, error diagnostics, and well-planned maintenance cycles are just the beginning. In the future, it is conceivable that we at the Siemens' MindSphere Application Centers for Rail will be able to download a vehicle's complete database via a cable, as is now possible with airplanes, in order to review the data for anomalies.

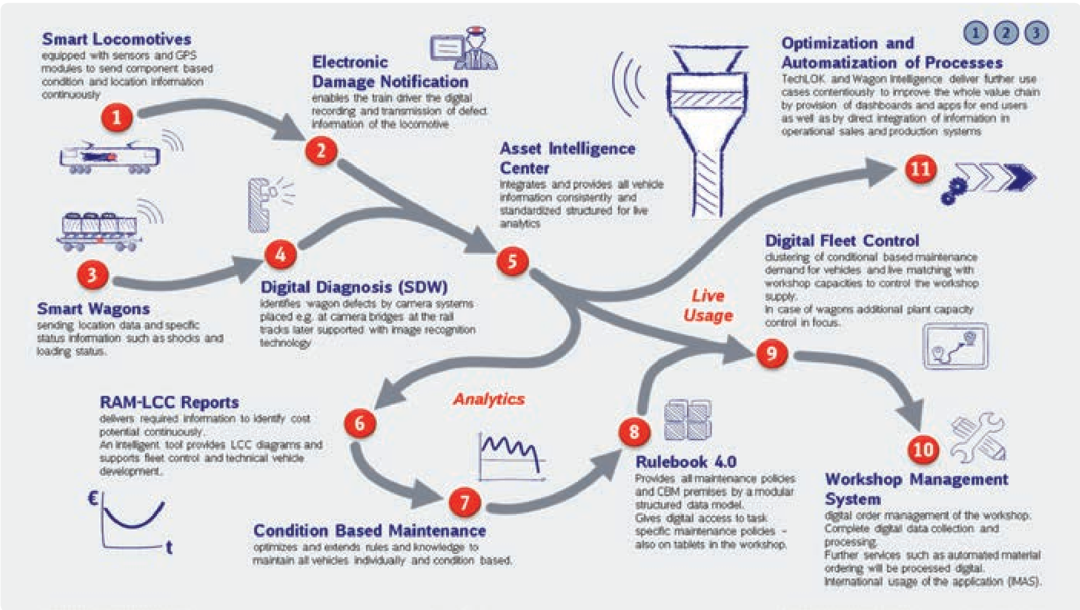
GERHARD KRESS
Head of the MindSphere
Application Centres for Mobility
Siemens Mobility Division



DB Cargo AG has commissioned Siemens to equip its locomotive fleet with a system for condition-based, predictive maintenance with a view to improve the availability and energy efficiency. The upgrade applies to Siemens locomotives of the 152 Series Eurosprinter ES64F and locomotives of the 170 and 191 Series, both Vectron types. For the 152 Series locomotives, Siemens will retrofit the necessary telemetric systems and network all locomotives with the **TechLOK system** used by DB Cargo. The telemetric systems continually collect data on the condition of the locomotives. With these data, experts at Siemens' Mobility Data Services Center will work with DB Cargo to develop applications and data analytics models. The system TechLOK is being implemented by DB Cargo's subsidiaries in four countries: Poland, Great Britain, France, and Germany. About 2,000 locomotives of 16 types will be interlinked by 2019 drive significant efficiency improvement.

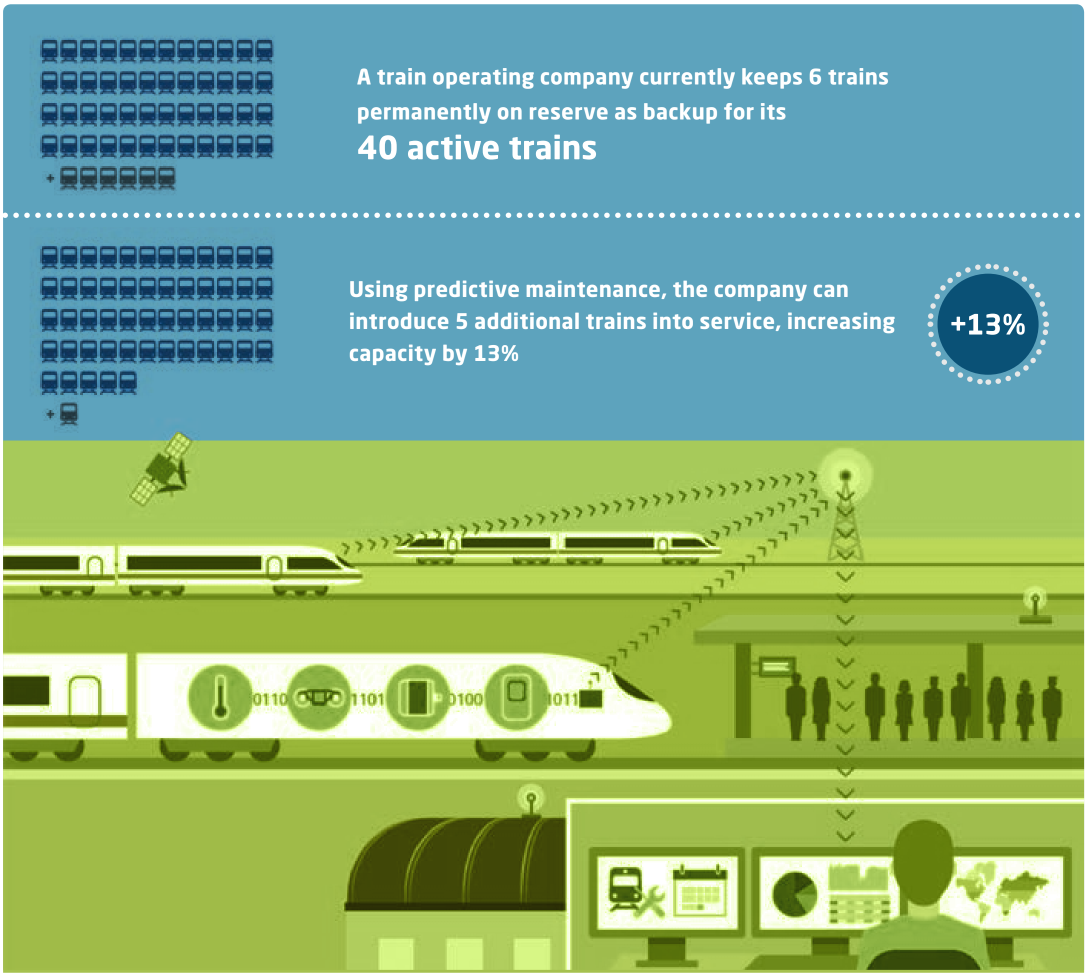
Source: Siemens AG (2017)

TECHLOK PROJECT:
ASSET & MANAGEMENT DIGITALISATION



Source: DB Cargo AG (2017).

EXAMPLES OF PREDICTIVE MAINTENANCE AND ITS BENEFITS



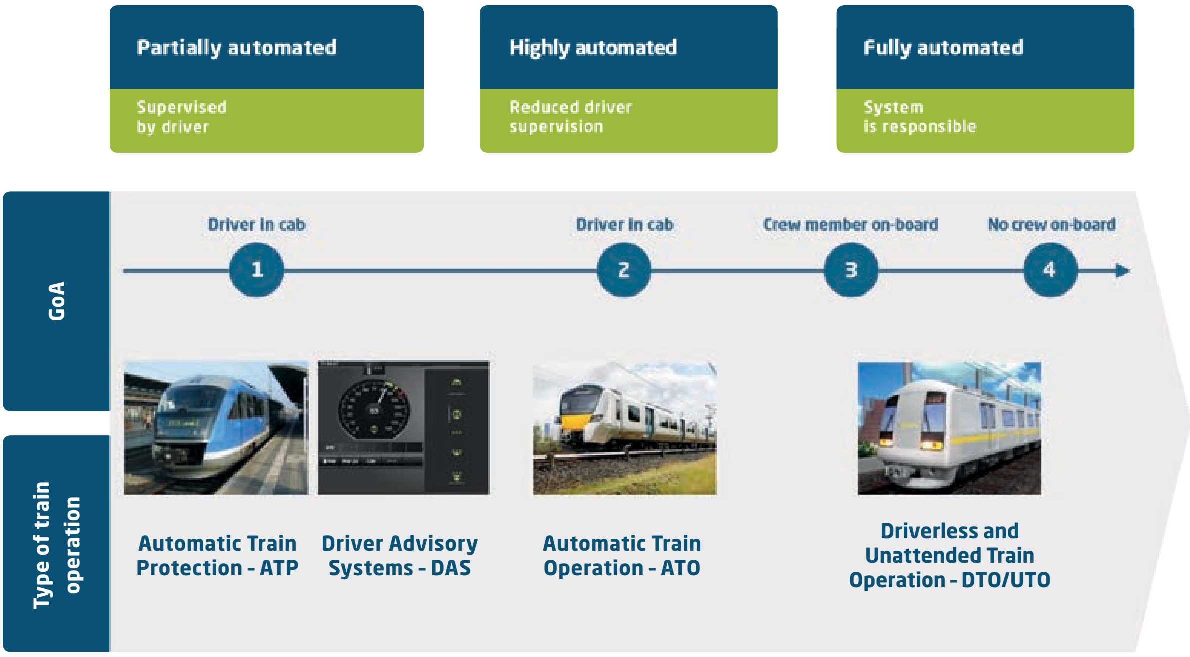
Railway line/ Train	Direct benefits	Value added
Barcelona – Madrid	RENFE use predictive maintenance in a commitment to run punctual Barcelona-Madrid service. Reduced operational and capital costs for train operators	Helping to gain market share against the competing air route. Reduced environmental impact of travel
Eurostar	Monitoring of critical components minimises train defects which can cause serious delays under the channel. Increased rolling stock availability leads to improved effective capacity and more services on offer	Helping to protect the reliability of the system and the Eurostar brand
Russia Velaro	Maximising availability and minimising outages	Promotion of the flagship product
Thameslink	Will effect availability above the 99.9% mark	Helping ensure connectivity across London

Source: Siemens AG (2017).

4. GOA4:
AUTOMATION AND INTEGRATION OF TRAIN CONTROL SYSTEMS

In rail transport, the development of autonomous systems has been spectacular mainly in the area of in public transport services, such as: driverless metro lines, light rail transit (LRT), people movers, and automated guided transit (AGT). In these systems, automation refers to the process by which responsibility for operation management of trains is transferred from the driver to the train control system. Following The International Electrotechnical Commission (IEC) standard 62290-1, there are four **Grades of Automation (GoA)**. The highest, GoA 4 describes a system upgrade in which vehicles are run fully automatically without any operating staff onboard.

GRADES OF AUTOMATION AND TRAIN CONTROL SYSTEMS



Source: Siemens AG (2016).

In the over 30 years since the launch of the first **AUTOMATED METRO LINES**, the growth rate for driverless metro has doubled in each decade – an exponential growth that is bound to quadruple in the coming decade. As of the beginning of 2018 there are almost 1,000 km of automated metro in operation, in 62 lines that together serve 41 cities in 19 countries. Current forecasts, based on projects approved for implementation, indicate that by 2025 there will be over 2,300 km of fully automated metro lines in operation.

FULLY AUTOMATED METROS WORLDWIDE (as of January 2018)

996 km	62 lines	41 cities	19 countries

Source: UITP (2018).

Siemens is a global market leader of signalling solutions for highly and fully automated mass transit solutions, including **Communications-Based Train Control (CBTC)**. By 2016, Siemens had equipped about 300 kilometres of lines worldwide with signalling technology for fully automated operations.

SIEMENS'S PROJECTS: AUTOMATED METRO LINES BETWEEN 2008-2016

Highly automated (GoA2)		Fully automated (Go3-4)
Beijing, line 10 (2008)	Istanbul, line 1 (2010/12)	Nuremberg, line U3 (2006)
Budapest, line 2 (2008)	Suzhou, line 1 (2012)	Barcelona, line 9 (2009)
Guangzhou, lines 4 and 5 (2008/10)	Guangzhou Guang-Fo (2010/12)	Paris, line 1 (2011)
Paris, lines 3, 5, 9, 10, 12 (2009)	Chongqing, line 1 (2011/12)	Sao Paulo, line 4 (2012)
Algiers, line 1 (2010)	Beijing, Olympia line 8 (2012/13)	Budapest, line 4 (2012)
Nanjing, line 1 and 2 (2009/10)	New York, PATH (2017)	Kuala Lumpur (2017)

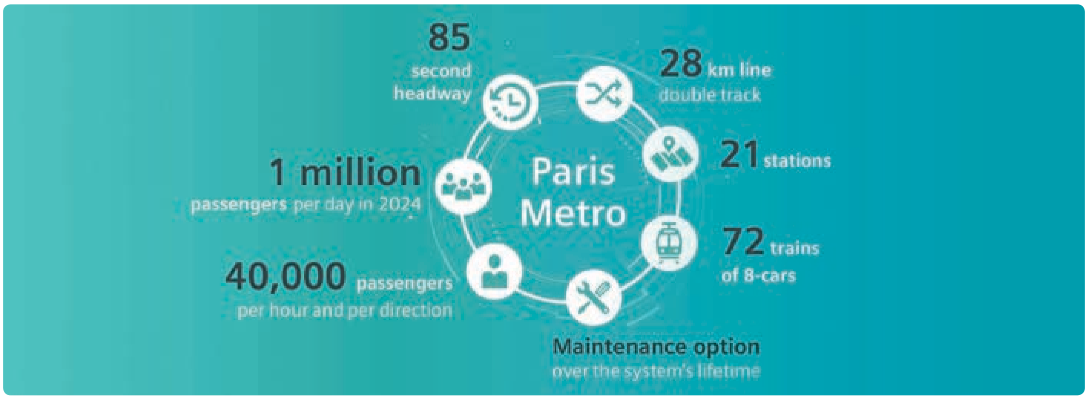
Source: Siemens AG (2017).

In the coming years Siemens's **Trainguard MT CBTC** signaling system will be used for the new fully automated metro lines worldwide, including Malaysia, France, Bulgaria, and Singapore. In Malaysia, the system will be installed for the planned Light Rail Transit 3 Line (LRT3) in Kuala Lumpur. The new fully automated line covering the length of 38 kilometers and one depot, is expected to be completed in February 2021.

Siemens is also to supply a CBTC system for GoA4 for the planned 2.2 kilometers Downtown line 3 (DTL3) extension in Singapore. This line is not only the world's longest suburban automated metro line, but it is also benefiting from the most advanced CBTC technology: it enables the operator to strengthen the capacity and availability of the network, and contributes to the improvement of the passenger experience of up to half a million people who commute daily within the Singapore rail mass transit network.

Siemens's Trainguard MT CBTC solution will be delivered for metro line 14 in Paris. This line is the backbone of the Grand Paris Express, the planned new fully-automated transit network for the French capital. It is the largest transport project in Europe and it will support the development of the Greater Paris into a sustainable metropolitan area. Both systems in Singapore and Paris are expected to go into operation in 2024.

SIEMENS'S TRAINGUARD MT CBTC FOR PARIS METRO LINE 14



Source: Siemens AG (2018).

Siemens is also a leading rolling stock supplier for fully automated metro lines. In July 2017, a new generation of trains from the **SIEMENS INSPIRO** family started to operate on a fully automated metro line opened in Kuala Lumpur. The Sungai-Buloh – Kajang is the first of the three lines planned within the project for the development of public transport in Klang Valley. The 51-kilometre long railway line with 31 stations will be served by 58 trains that can carry 1,200 passengers per trip each for a daily capacity of 400,000 passengers.

SIEMENS'S INSPIRO PLATFORM allows for up to eight-car train configurations with varying degrees of automation – up to GoA4. The interior can be equipped with longitudinal, transverse, or mixed seating configuration, depending on the customer's requirements. In addition, the length and width of the carbodies can be varied. The trains can also be configured with three or four doors per side – with outside sliding or sliding-plug door types as options.

The INSPIRO's energy efficiency is dependent on two factors – its weight-saving design and energy-efficient technologies applied. The light-weight carbody and a weight-optimized bogie reduce the overall weight of a single car by more than three tonnes compared with the previous generation. The low operating and maintenance costs, reduced energy consumption, and the natural and recyclable materials used offer benefits for operators and the environment alike. Inspiro's environmental impact has been reduced throughout the entire product lifecycle. As a result, the train has a recyclability rate of up to 95% at the end of its service life (UNIFE Recyclability Calculation Method for Rolling Stock).

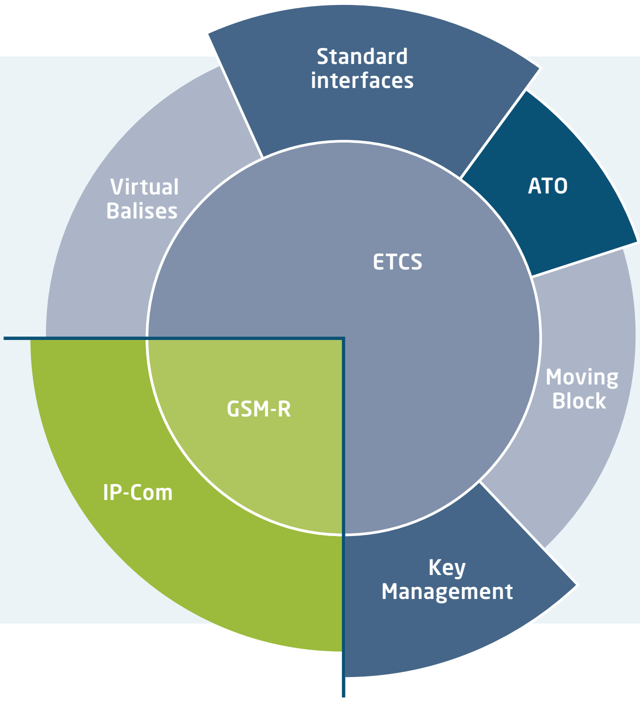
Siemens will also deliver a fully automated **AIRVAL PEOPLE MOVER** for Bangkok Airport (scheduled to begin service in 2020), as well as Frankfurt Airport (2023). Fully automated two-car trains will be equipped with the Trainguard MT.

The discussed innovative solutions for automation in rail transport render a range of benefits for the systemic operations as well as their environment: they increase the track capacity, the reliability of service, improve safety and energy efficiency, as well as reduce noise and vibration.

Autonomous trains are bound to increase their share in urban mobility systems.

Apart from implementing autonomous train service on metro lines, i.e. in closed systems with short intervals between services and high frequencies, another challenge will be the introduction of **Automated Train Operations (ATO)** in urbanised areas for regional and cross-country trains. A combination ETCS with ATO is a promising solution for future fully-automated operation for mainline services. ETCS monitors the train's movement to ensure it adheres to the local speed limit and its own permitted top speed. The system can be scaled up to different levels. For example, at Level 2, the required GSM-Railway radio channel enables both the train-track communication for the ETCS itself and the communication between the trackside Automatic Train Supervision (ATS) and ATO.

Technically, this means that ETCS is a train control and protection system that acts as an intermediary between the vehicle and the track to ensure railway safety and that conveys driving instructions from the track to the vehicle. The so-called balises installed on the track serve to retrieve this information along with precise positional data. ATS system coordinates train movements. ATO, on the other hand, is a control system which, like a train driver, controls acceleration and braking along with such functions as door movements, and translates the calculated energy-optimized trip profile into precise control commands to the train's drive and braking systems. It does all this within the secure framework defined by the ETCS, which is why the system is referred to as **ATO over ETCS**.

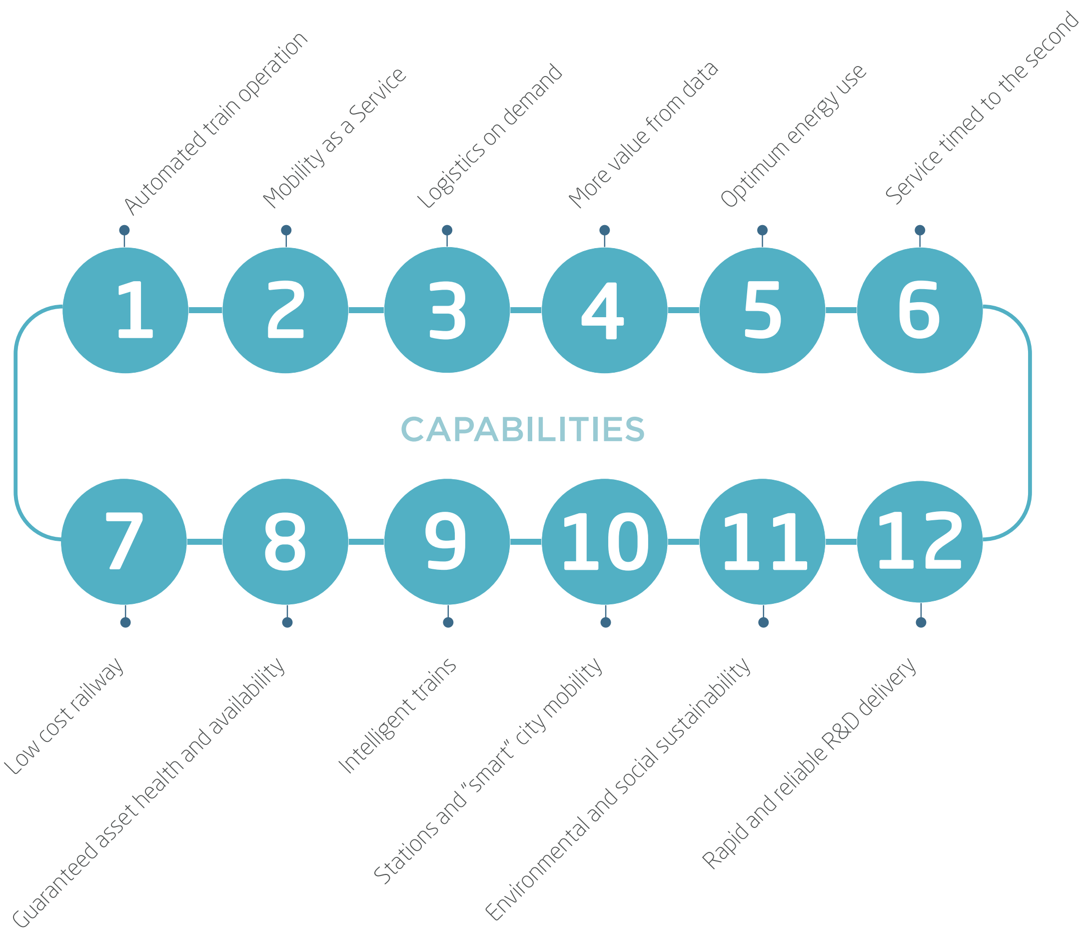


The advantages when ETCS is combined with ATO are particularly through improved energy efficiency and greater line capacity. ATO shortens headways through time-optimized driving, plus it enables for precise stopping at defined positions, automatic door opening, definition of exact stopping times for the driver, and precise travel along ETCS braking curves. Aided by ATO, the train uses line data, schedule data and real-time information from the infrastructure to drive at an optimized speed profile, thus making additional energy savings.[13]

Enhancing the advanced traffic management and control systems without impacting the ERTMS core, and, where appropriate and necessary, providing backward compatibility to protect investments both in mainline and urban railways constitute the key challenge within the Innovation Programme II in the European initiative dedicated to research and innovation in the railway sector – **SHIFT2RAIL**.

Digitalisation and automation are at the core of twelve Innovation Capabilities of the Shift2Rail vision which will enable the railway sector to produce value-adding products and services, and increase network capacity.

TWELVE CAPABILITIES REQUIRED FOR THE REALISATION OF THE SHIFT2RAIL VISION



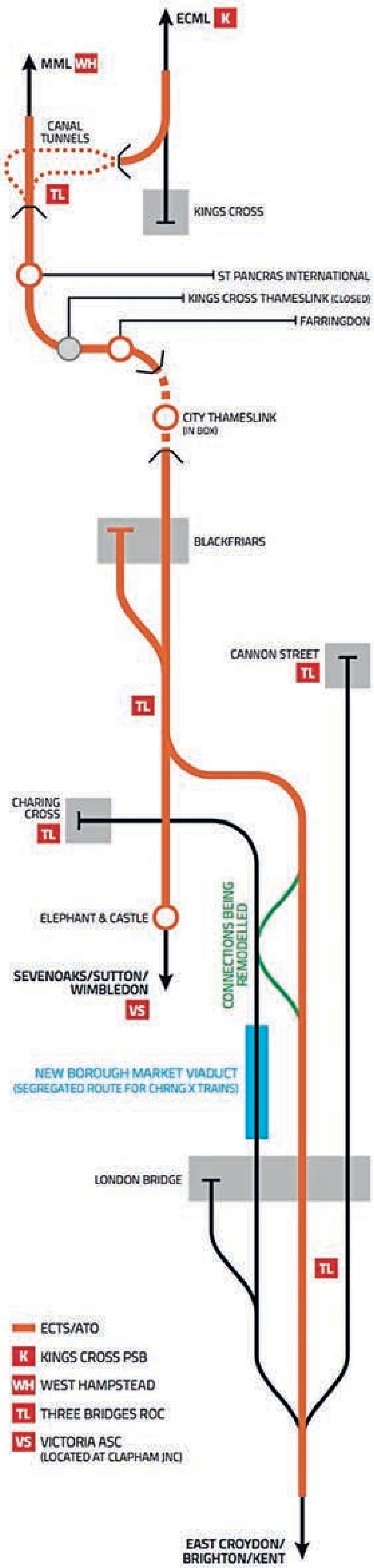
Source: Shift2Rail JU (2018), S2R MULTI-ANNUAL ACTION PLAN, Executive View, Part A, p. 30.

Digitalisation, as key to businesses, is now demonstrating how its use will help meet customers' expectations, drastically improving manufacturing, operations and maintenance performance. The system-integrated adoption of digital technologies to deliver Shift2Rail Innovation Capabilities is central to this transformation.

Optimised rail solutions mean smart use of existing networks, i.e. maximised use and rightsizing of capacity based on demand, and of assets, i.e. maximum availability, but also return on investment, i.e. low life cycle costs. Those are the main objectives of Shift2Rail: cost-efficiency, punctually and the increase in capacity.

The S2R partnership will deliver an integrated Research & Innovation in automation, traffic management, seamless and attractive intermodal mobility for passenger and business, intelligent rolling stock, self-monitoring and maintenance infrastructure, paving the way toward the future of mobility.

CARLO BORGHINI
Executive Director,
Shift2Rail Joint Undertaking



THAMESLINK PROJECT: A DIGITAL MILESTONE FOR THE RAIL INDUSTRY

On 17 March 2018, Govia Thameslink Railway (GTR), Network Rail and Siemens completed the world's first ATO – ETCS system on the mainline railway during passenger service. An eight-car train automatically brought itself to a stop at London St Pancras International after having transitioned into ETCS Level 2 Full Supervision and then ATO on its approach.

ATO will initially operate on GTR's network between St Pancras and Blackfriars in May 2019, then extended to London Bridge around six months later. The latest ATO technology has been fitted to 115 new Siemens's Class 700 Desiro City trains.

According to GTR, the automated system will allow the operator to run up to 24 trains per hour in each direction, providing 70% more seats through the centre of London, linking new communities and cutting journey times for thousands of passengers.

Implementation of ATO – ETCS solution within the THAMESLINK Programme is a milestone for the rail industry on its digital transformation. This innovative solution will bring a totally new added value in the integration of rail transport in urban areas.

The presented solution has raised interest followed by demand expressed in other cities across the UK, the Netherlands and Germany.

DSTW: DIGITAL INTERLOCKING

In March 2018, Deutsche Bahn AG inaugurated Europe's first digital interlocking for trains (digitales Stellwerk – DSTW) which began operation in Annaberg-Buchholz, on the Erzgebirgsbahn in southeastern Germany, ushering in a revolution for rail control and safety systems. Characteristic for the new interlocking architecture is that the dispatcher's switching commands are transmitted to the points, signals and track contacts via network technology. As a result, the previously-required individual connections to the individual interlocking elements partly via kilometer-long cable bundles have been eliminated. Signals and points can now be controlled from much greater distances with the DSTW network links via a data line.

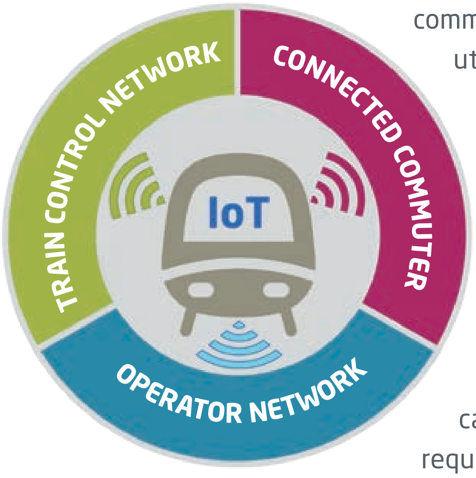
Annaberg-Buchholz represents one of the biggest technology projects in the history of Deutsche Bahn. Intelligent communication networks and their associated standardized and modularized technology are setting the trend for the coming years. They enable us to operate rail transport more economically, while saving resources and ensuring greater efficiency for our customers. The new interlocking technology is thus a milestone in the digitalization of rail infrastructure and will be the basis for higher capacity and improved punctuality in rail transport.

MICHAEL PETER
CEO, Siemens Mobility Division

The solution used in Annaberg-Buchholz is an important step toward interlocking in the cloud. For the first time ever, an interlocking transmits its IP-based commands to the system's field elements such as points and signals. This allows for completely new levels of flexibility in planning, makes possible the use of intelligent field elements, and will generate positive longer-term cost effects. And all this is achieved, of course, while meeting the strictest safety standards for operations.

The DSTW system in Annaberg-Buchholz marks the beginning of a country-wide implementation of the new and innovative interlocking generation. The technology can be used for operations on main lines with heavy traffic and major hub railway stations as well as for less complex applications in rural areas.

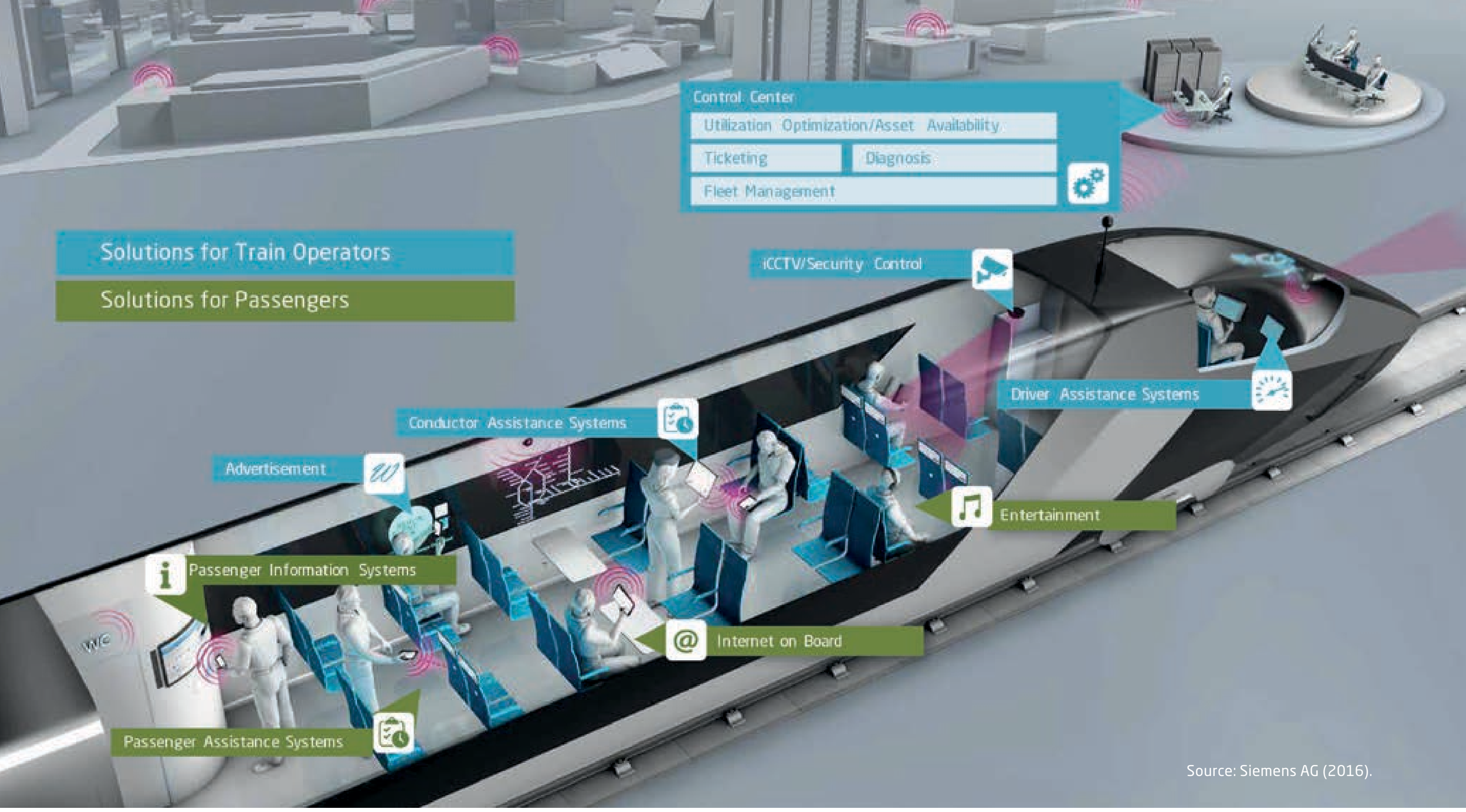
5. INTERNET OF TRAINS: CREATING VALUE FOR MULTIPLE STAKEHOLDERS



An example of how the concept of the Internet of Things is implemented in rail transport is **THE INTERNET OF TRAINS**, or The Connected Train, whereby the train's smart sub-systems communicate data via cloud computing to the central data platform. To be able to utilise the functionality of the Internet of Trains, reliable and uninterrupted communication is necessary between three different networks: one providing the connection between the train components and the on-board controls, one used by the crew on-board (for example, VLAN-based) and one broadband mobile internet connection service offered to passengers. A prerequisite for the implementation of IoT is an operation of the GSM-R standard, a mobile internet system dedicated for rail transport and one of the two key components of the European Rail Traffic Management System (ERTMS). It is expected that progress in this area will follow especially in the case of those solutions offered to rail operators and passengers that are not required to be homologated.

KRZYSZTOF CELIŃSKI
Division Director,
Siemens Sp. z o.o.
Mobility

By implementing the latest digital technologies in railway industry, we improve safety as well as capacity and reliability of the whole railway system, while creating new employment opportunities for the young generation. Among the most crucial solutions are those related to customer service, such as information and ticketing systems as well as the maintenance of rolling stock and train control systems. In the era of ongoing technological advancement, trains that always follow the schedule has become a viable vision, owing to such new tools as Internet of Things, continuous monitoring of stock in motion and smart forecasting with the use of Big Data tools. Siemens has coined the term Internet of Trains to embrace these innovative technologies.



Source: Siemens AG (2016).

THE ADVANTAGES OF THE IMPLEMENTATION OF IoT SOLUTIONS FOR PARTICULAR STAKEHOLDERS

THE MANUFACTURER

- real-time access to information about particular train components helping prevent defects

THE TRAIN OPERATOR

- a better understanding of the passenger's needs
- the possibility to offer embedded services in cooperation with partners
- real-time maintenance data updating allowing for predictive maintenance

INFRASTRUCTURE MANAGER

- real-time access to data about the location and movement of trains helping reduce safety hazards and helping plan and carry out infrastructure maintenance.

IT PLATFORM OPERATOR

- the possibility to offer embedded services in cooperation with partners
- added value of services created by digital business models

PASSENGERS

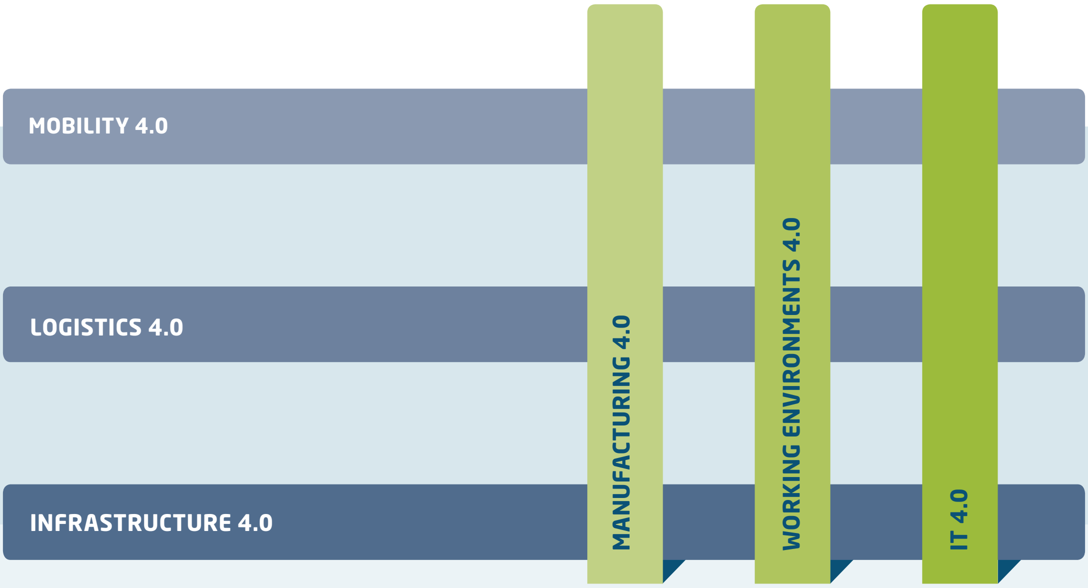
- access to online services even when not onboard trains (social media, film hubs, playlists, digital libraries, newsstands)
- automatic ticketing and payment processing
- fast and flexible journey planning

DIGITAL BUSINESS STRATEGIES OF RAILWAY COMPANIES

1. DB 4.0:
INVESTING IN START-UPS

DB 4.0 Programme is an example of a comprehensive digital transformation strategy designed for a railway holding. It involves initiatives in all areas of DB's business activity.

DB 4.0 - CONCEPT OF DIGITAL TRANSFORMATION



Source: Deutsche Bahn (2016).

The three currently prioritised areas of digital transformation in DB are:

- the development of the customer interface
- supporting operations, including the maintenance of infrastructure and rolling stock
- designing new business models that reach beyond the basic business activity, including the Qixxit platform.

The address these priorities, DB is prepared to continue its investment in the development of start-ups. Between 2015-2016 the implementation of the concept crowdsourcing allowed DB to launch a number of initiatives to create innovative solutions that monitor and analyse the customers' expectations and emotions. These include: DB Mindbox, Zukunft Bahn, skydeck, d.lab. The co-ordination of these projects is a responsibility of the newly-created entity DB Digital Ventures GmbH, The start-up ZERO.ONE.DATA (ZOD), initiated by DB Systel launched the DataBOX data exchange platform. One of the most recent initiatives is the Beyond1435 programme, a start-up co-launched by Plug and Play platform. In collaboration with Hyperloop TT, DB is developing a prototype of a train with augmented windows, with the envisaged completion year 2018. Finally, DB is looking to introduce autonomous trains into regular scheduled service by 2021. Consideration is also being given to the feasibility of the development of autonomous cars that could be used by railway passengers to reach the train station or their final destination.

DIGITAL RAIL: A KEY OPPORTUNITY FOR GERMANY

Source: Deutsche Bahn AG (2018).

2. PKP GROUP: STRENGTHENING INTERACTION WITH CUSTOMERS

MIROSŁAW ANTONOWICZ
Ph.D.
Member of the Management Board, PKP SA,
Director of the Scientific Center of Transport and Logistics, ALK

Innovative technologies and the growing expectations of customers regarding the level of service provided increase the importance of digital economies. Digital transformation is inevitable, but also crucial to increase the rail industry's capacity for growth and development on the market of transport services. In PKP Group, this involves initiatives meant to improve customer interactions, with the deployment of ICT and infrastructure management systems.

The progressing digitalisation entails a consolidation of technologies and business processes within the group as well as reaching beyond the group, which, in turn, is improving the face value of the industry and remodelling the ways in which it operates. It fosters the development of new business models which are based on the consolidation and management of competencies of particular co-working entities.

Examples of digitalisation-driven projects are:

- shared ticketing, whose main objective is the improvement of the convenience of travelling on trains belonging to different operators, therefore, a standardisation and improvement of service accessibility – **IMPROVEMENT OF CUSTOMER SERVICE**

- MPLS, the development of broadband data transfer – **IMPROVEMENT OF ICT INFRASTRUCTURE**

- e-invoice, the development of collecting, transmission and processing of data in a digital form within the group to make use of the internet's potential and thus improve the interoperability, using the developing ICT sector – **IMPROVEMENT IN THE AREA OF BUSINESS PROCESSES**

- the creation of Centre for Security of Operations, responsible for the ongoing monitoring of the transfer of data within the organisation and responding to security incidents and violations – **IMPROVEMENT IN THE SECURITY OF DATA PROCESSING**

- implementing the latest technologies to increase security on PKP premises, especially, **IMPROVEMENT IN THE SECURITY AT STATIONS AND ON TRAINS**

- the digitalisation of surveying centres by digitising existing maps and the creation of relevant databases (improvement of customer service and project management)

- the creation of a logistics orchestrator, involving a logistic platform and an internet portal, that will offer services in logistics and link together the members of the logistic system – **IMPROVEMENT OF THE CONSOLIDATION OF SUPPLY CHAIN**
- the implementation of crowdworking at stations – **INVOLVEMENT OF PASSENGERS IN CREATING NEW SOLUTIONS**.

JAKUB MAJEWSKI
Ph.D.
President of the Management Board, ProKolej Foundation

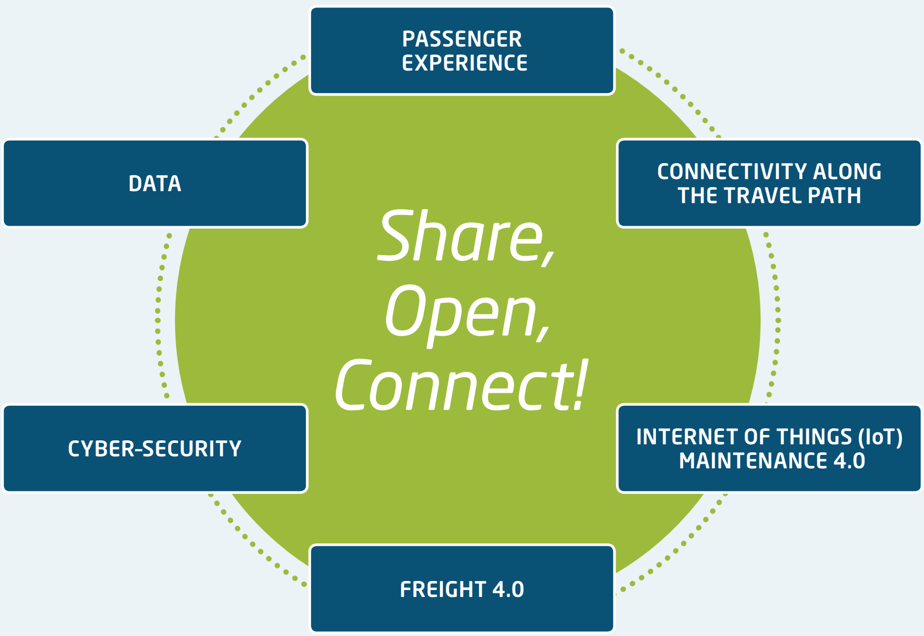
At the time of its creating and the following rapid development, railways were among the most innovative sectors of the world's economy. The railway companies built and operated railway lines made significant contributions to the world's both technical-technological and organisational and cultural progress. Unfortunately, the subsequent rapid development of the automotive industry, and, later, air transport, the rail industry surrendered its leadership. Undercapitalised and somewhat underappreciated, it left the mainstream of digital economies. In an effort to counter this the major railway companies as well as their suppliers launched vast investment programmes, start-up incubators and actively sought support of researchers. The potential for the development of new digital solutions for rail transport cannot be underestimated, ranging from such areas as smart infrastructure and stock to monitoring systems, management solutions, customer relations, to own innovative ideas.

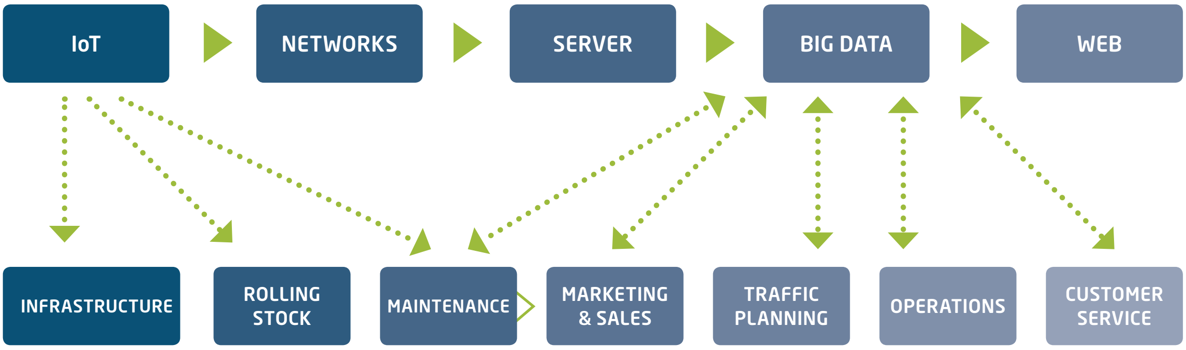
3. UIC:
A COMMON DIGITAL PLATFORM

The digital solutions mentioned in this report were, are being or will be created within particular rail companies' and networks' ecosystems. Meanwhile, a consolidation of solutions on an international level still remains a major challenge. The progress of digitalisation will be followed by still new challenges connected with cybersecurity.

DIGITAL PLATFORM initiative promoted by International Union of Railways (UIC) is intended to provide a platform on which member entities will be able to share good practices and co-ordinate motions to promote and develop digitalisation within rail transport. The motto of the platform is: *Share information, open data, source, innovation, services, connect people, objects* with an immediate link with security.

KEY FIELDS OF UIC DIGITAL PLATFORM AND ITS ARCHITECTURE



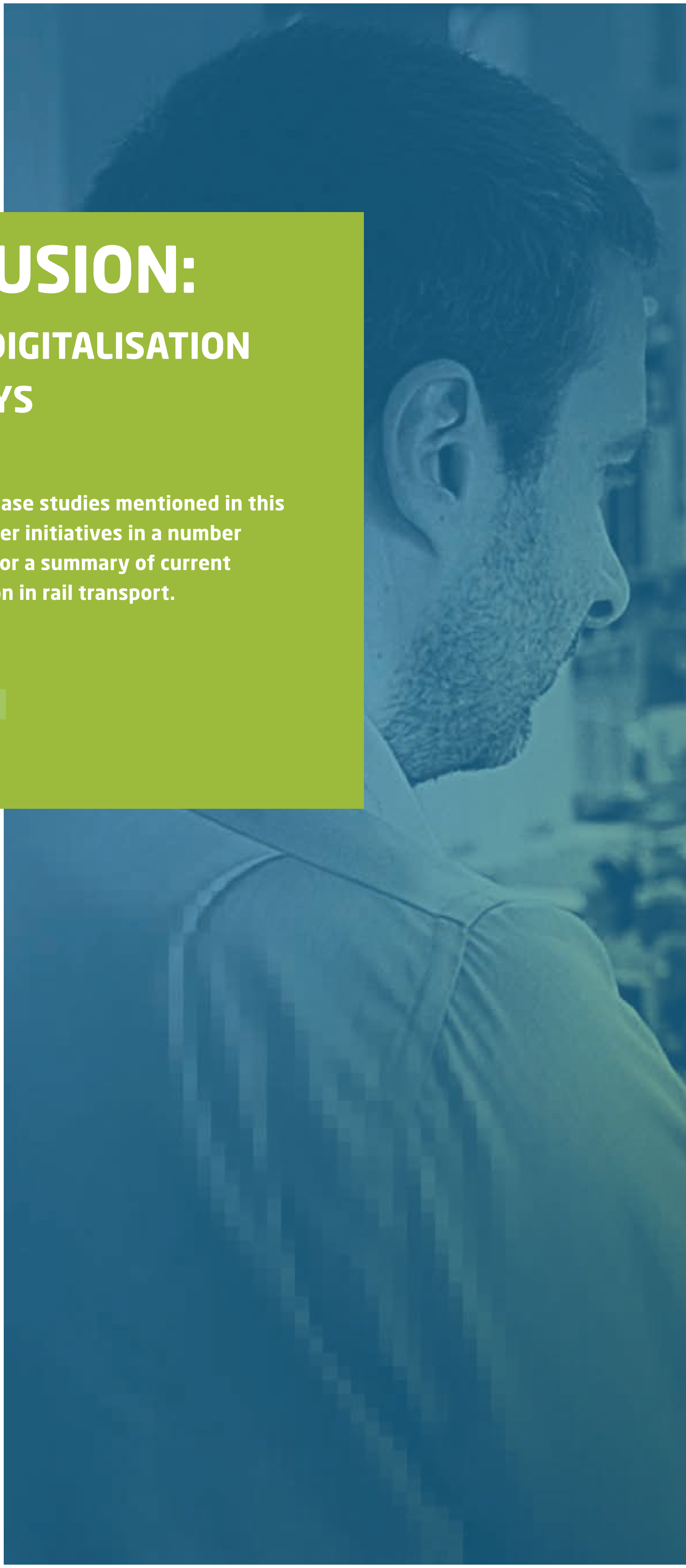


Source: UIC (2017). Digital Railway Developments, Progress Paper, 4th version, June; Bedel, F. (2017). UIC DIGITAL Platform, Presentation for The Future of Transportation Conference, Cologne, 6 July.

CONCLUSION:

AREAS OF DIGITALISATION OF RAILWAYS

The analysis of the case studies mentioned in this report as well as other initiatives in a number of countries allows for a summary of current areas of digitalisation in rail transport.



Key technology	Digital concept for railways	Solutions examples
PASSENGER SERVICES		
Broadband **Mobile internet** **Big Data Analytics** **Cloud computing**	Connected commuter Intelligent station Smart ticketing Mobility as a Service	Internet access on-board trains (3G/4G, potentially 5G) Mobile applications, including intermodal travel Embedded services and infotainment on-board trains and at railway stations Systems integration via interoperable product service interfaces (IPSI) Dynamic/Real-time Passenger Information Systems Automatic ticketing and information systems
FREIGHT SERVICES		
Internet of Things	Logistics 4.0	Real-time train and freight cars tracking and tracing systems
Big Data Analytics	Freight as a Service (FaaS)	Electronic shipping documents and e-invoices
Cloud computing	Intelligent freight car	New business models for freight logistics
Robotics	Logistics Platforms	The use of drones to monitor trains and ensure safety of cargo

Digital transformation fares beyond the digitation of data and processes. Instead, it involves an ongoing adaptation to changes in a turbulent environment. This creates both opportunities and threats for any industry, not less the rail industry.

The challenge to be addressed in the coming years is not only a switch from electro-mechanical to electronic devices followed by a switch to digital components, the implementation of fully automated systems based on standard interfaces and safety certification, but first and foremost, a general change of the mindset to one allowing for sharing of resources, consolidation of business solutions and the creation of new value of rail services both within and outside rail ecosystems.

Key technology	Digital concept for railways	Solutions examples
INFRASTRUCTURE & ROLLING STOCK MANAGEMENT		
Internet of Things	Infrastructure 4.0	Infrastructure monitoring systems
Cloud computing	Maintenance 4.0	Predictive maintenance (PM)
Big Data Analytics	Self-aware infrastructure	Wayside Train Monitoring System (WTMS)
Robotics	Self-aware rolling stock	Dynamic railway infrastructure access systems
MANUFACTURING		
		New technologies and materials
Additive manufacturing	Smart factory	3D technology
Robotics	Virtual manufacturing	Virtual Reality (VR)
Big Data Analytics		Industrial Internet of Things: integration IT and OT
SIGNALLING & INTEROPERABILITY		
Broadband		Implementation of GSM-R and ERTMS standards
Mobile internet	Connected train	Cyber-security standards (NIS Directive)
Internet of Things	Internet of Trains	Ethernet Train Backbone Network (ETBN)
Cloud computing		Automated Train Operation (ATO)
Big Data Analytics		ATO over ERTMS solutions

The digital challenge for railway sector is how to connect the customers, the operators, the trains and the infrastructure and transform to network effects.

A key consideration in this regard is ensuring that the senior management of rail companies maintain uninterrupted focus on monitoring of the changes and hyperawareness of what impact new technologies have on the expectations of customers, business partners, the personnel, while being wary of the competitors' behaviour.

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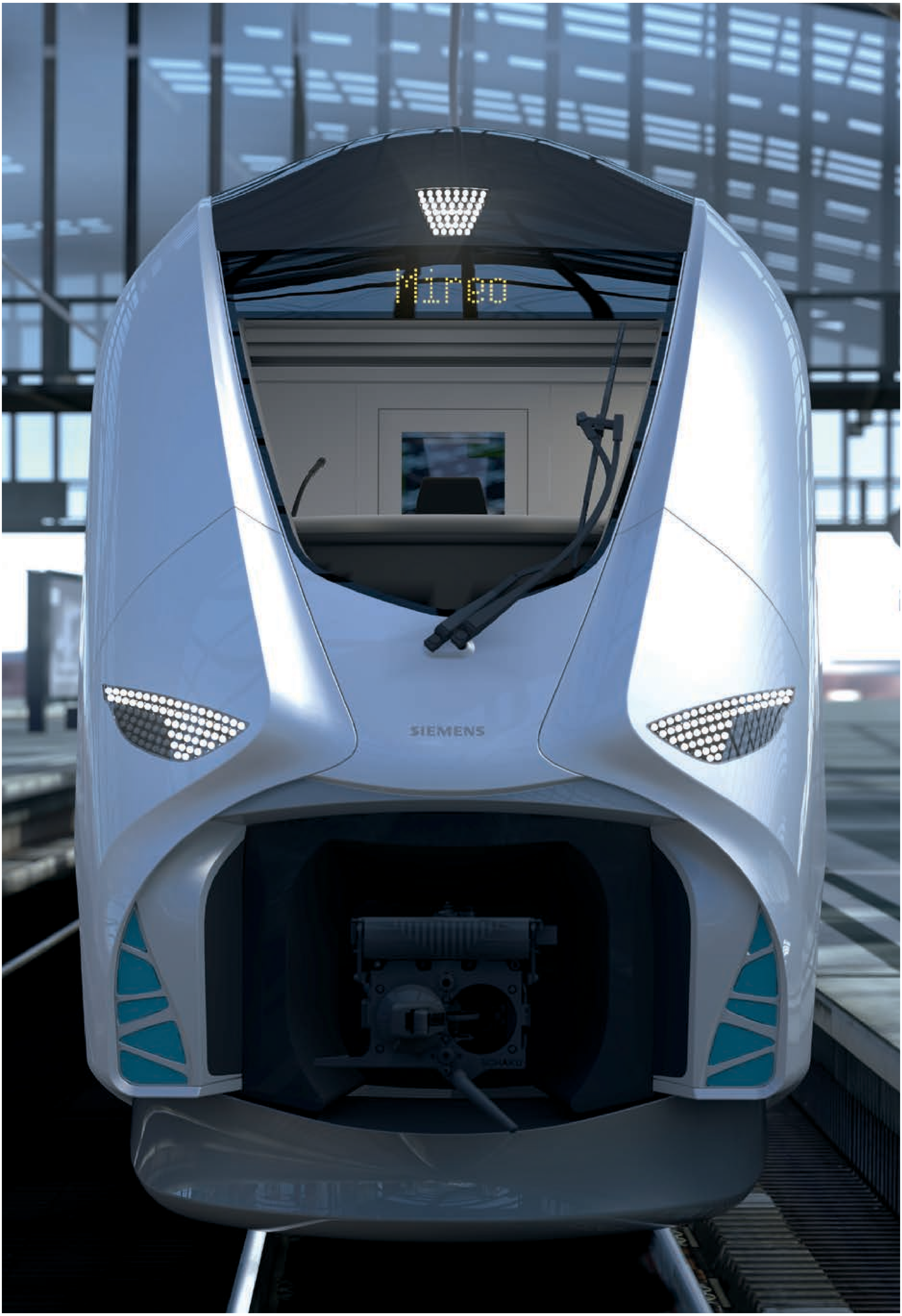
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This report summarises the directions of digitalisation initiatives in rail transport. New products and services, as they become a part of operations of railway undertakings, infrastructure managers and manufacturers, will create added value for multiple stakeholders in the transport process, and will contribute to the implementation of new concepts of mobility in the future. The consolidation of digital technologies and business processes in the sector remains an outstanding challenge.

The report was prepared in collaboration between representatives of science and railway industry.