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Overview of the Areas of the Railway Research Institute Activities

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Summary
Railway transport employs mechanical, pneumatic, electrical, electrotechnical, relay, and electronic programmable solutions, as well as hydraulic, optical and laser-based solutions for the construction and everyday exploitation of various infrastructure and rolling stock functionalities and for supporting and documenting both operation and maintenance. The safe and reliable operation of railways depends, to a significant extent, on the proper interaction of the various technical and procedural solutions. It is based on normative documents, approval procedures and rules regarding handling technical, operational and organisational changes. The article presents the railway system's technical complexity as well as types and formal constraints of the normative and legal documents defining technical and procedural requirements, using both of them as a background for showing the Railway Research Institute's areas of activities from technical competencies and research facilities used in approval processes to involvement in the development of normative documents.

Keywords: railway infrastructure, railway rolling stock, approval processes, normative documents

1. Introduction

Railway transport uses diverse technical and procedural as well as formal and legal solutions. Most railway transport professionals are competent and work in a relatively narrow areas, e.g. construction and repair of railway permanent way, or ongoing maintenance and operation of rolling stock. Yet, the proper, safe and reliable, functioning of the railway largely depends on the proper interaction of technical and procedural solutions applied in different areas. The appropriate relationship between them is ensured by using normative documents that determine for example, on one side, the material, strength and quality requirements, as well as dimensions and geometry of the rails, including e.g. the maximum rail head side wear limits, and on the other side, the material, strength and quality requirements, as well as dimensions and geometry of the wheels, including e.g. the wheel flange wear limits.

These normative documents are of a different formal and legal nature and vary in detail. Moreover, they change over the years. More frequently in case of more sophisticated technologies. As a result programmable digital solutions are subjected to the most rapid evolution of normative documents. This is a major challenge considering the long lifespan of the railway infrastructure and rolling stock, which may be as long as several decades. As a result in case of creating normative documents, on one side technical solutions that are already approved and in service shall be taken into account, and on the other side, it is necessary to diligently carry out technical and quality reviews, which have to be processed in compliance with the relevant formal and legal requirements.

The relevant competencies are maintained by the Railway Research Institute, which carries out scientific work, research and approval processes for rail transport, including railway transport, as well as the railway standardisation committees of the Polish Standardisation Committee – PKN/KT61 and PKN/KT138. The Railway Research Institute is also actively involved in the work of the European forum for the coordination of certification bodies under the Railway Interoperability Directive. In this context, it is vital that the Institute has built up and maintains competencies and test stands in all key technical areas used in rail transport.

This article provides a brief overview of the Railway Research Institute's areas of activities, demonstrating how the Institute's staff and research infrastructure contribute to ensuring the proper, safe and reliable operation of railways.

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2. Technical and Procedural Solutions Constituting Railways

Any transport system includes the transport infrastructure, the means of transport as well as operational procedures and rules regarding documenting operations. For railways, the infrastructure comprises railway lines and stations, as well as various types of sidings, junctions and loading points. The means of transport include electric and diesel multiple units, locomotives, coaches and freight wagons, and special purpose vehicles e.g. for inspection, maintenance or repair work. The relevant procedures define the rules regarding operation and work of the traffic controllers, train drivers and various staff, whose work affects railway safety and reliability: from track inspectors and switchmen on the infrastructure side and coaches and wagons inspectors on the rolling stock side to the infrastructure manager's crisis management centre and the railway undertakings' control offices, which manage the rolling stock turn-rounds and organization of the work of the train crews.

Nearly two hundred employees of the Railway Research Institute are directly involved in various areas of rail transport over many years of their professional lives. It is not possible to cover all types of solutions and associated challenges in a single article, however to provide an overview of the railway system that makes it possible to grasp the important relationships, interfaces and dependencies between the different areas, the key solutions are described in twelve subsections.

2.1. The railway permanent way – from the subsoil to the rails running surface

The railway track seen by the passengers, which comprises rails, sleepers and fastenings fixing rails to the sleepers, cannot and is not placed directly on the ground. It is necessary to ensure adequate load transfer to the subsoil. Once the parameters of the subsoil have been verified, the track substructure is usually constructed bottom up using geonets, geotextiles, gravel and ballast. A ballast layer adapted to the expected loads is placed under the sleepers. Ballast is also laid between sleepers and on the sides of the track formation. Engineering structures like culverts, bridges, viaducts and flyovers are often present under the track. Large structures can be constructed with a ballast bed. However, due to the loads involved, more and more frequently ballastless bridge constructions on bridge sleepers or with slab tracks are increasingly utilised. Slab tracks are constructed from the bottom up or from the top down, depending on the type of track construction. Slab constructions, as the ones maintaining high strength parameters and ensuring long-term stability of the track geometry, are utilised especially for the high-speed railway lines. Special sealed slab track constructions are employed in the areas used for handling materials that shall not penetrate the ground. The tracks are equipped with drainage systems, cable ducts, and various structures for mounting the complementary equipment and systems necessary for such solutions as control command and signalling, data transmission and overhead contact lines.

Whether made of softwood or hardwood, wooden sleepers shall be adequately protected. In contrast, concrete sleepers degrade in a completely different way. Their various types differ in terms of reinforcement, concrete parameters and built-in fastening elements like plugs and anchors. Composite sleepers are also available, but not yet widely utilized. Several types of rails are used as well. Type 60E1 Vignole rails are most commonly employed for railways; however, other types of Vignole rails are also utilized. Tramway tracks utilize the so-called grooved rails. Special transition solutions are used on sections between different rail types, e.g. between 49E1 and 60E1. Rails are subjected to the defined material, strength, quality and operational requirements, e.g. regarding permissible wear. The fastening systems constitute separate complex solutions. Both, direct and indirect fastenings are utilized. Both can be rigid and elastic. They have to fit to the fastening elements in the sleepers. Moreover, they have to be able to withstand very high forces. For example, complete fastening systems have to be exposed to fatigue tests. Some plastic elements are used as fastening system components as well as track components like insulating pads and under-sleeper pads (USPs) minimising vibrations and improving interaction between sleepers and ballast. Additional noise-damping elements e.g. glued onto the rail web are also available. All shall be suitably durable and fulfil their function over years.

For trains to move in different directions, switches and crossings shall be provided. These are highly complex mechanical structures equipped with electric, or more rarely hydraulic, point machines/drives as well as switch rails position controllers. Multi-drive switches, sometimes with a movable nose of the frog, are utilized especially on the high-speed railway lines. It is not only the geometry and durability of the switch that becomes a challenge. Ensuring appropriate synchronization of the operation of multiple drives and controllers and their safe interaction with control command and signalling systems are also challenging.

Then there are also expansion joints – advanced mechanical load-bearing structures that protect tracks against buckling – used for example on and around long civil engineering structures, as well as track gauge changing facilities – special structures interacting with running gears adapted to different track gauges. Currently, the following track gauges are used in Europe: 1435 mm, 1520 mm, 1524 mm, 1600 mm, 1668 mm and locally also narrow-gauge tracks.

The tracks, switches and crossings shall guarantee adequate strength over their entire length but also maintain a strictly defined geometric layout, including curves, transition curves, cant ramps, rail track gradients, etc., up to equivalent conicity. Maintaining track geometry requires proper interaction between the track and the track substructure.

The track layouts shall be adapted to the anticipated railway operational needs in terms of the length and number of station tracks complementing the main tracks and main auxiliary tracks, as well as the availability of single and double crossover connections between tracks on sections between stations, as well as the length and availability of the sidetracks, shunting tracks and reversing dead-end tracks at the connections between main lines and sidings, etc.

The top of the rails as the track upper surface is strictly defined as the rail running surface. Its design depends on the type of track – European tracks use a different geometry than 1520 mm gauge tracks.

Each metre of the track shall maintain adequate strength regarding the load carried by the vehicles axles as well as adequate structure gauge. No element, e.g. overhead line supporting structures, trackside colour light signals and platforms, may protrude into the space envelope that shall be available for trains with the highest loading gauge permitted on the given line. Static, dynamic and kinematic loading gauge solutions are utilized. For example, consideration is given to differentiated suspension (dynamic movements of the rolling stock bodies and pantographs) as well as track position changes as a result of years of exploitation.

The track infrastructure is complemented by passenger stations and logistics centres comprising respectively platforms, platform access routes and station buildings appropriate for providing passenger services, and cranes, gantries, areas dedicated for storage of containers and operation of Reach Stackers as well as appropriate road and/or port infrastructure.

2.2. Signalling systems – from track and switch occupancy checking to trackside colour light signals

Trains are heavy. Pendolino, which is considered a light train, weighs 400 tonnes; the weight of the freight trains in Poland reach as much as 3 600 tonnes. The CMK Central Trunk Railway line was designed for trains up to 5 000 tonnes, but Polish railway undertakings have never run so heavy trains due to traction limitations. Passenger trains running at higher speeds are mostly light trains. In comparison, heavy freight trains run slower. The length of the braking distance increases with weight, but also with the square of the speed. As a result braking distances of passenger trains are comparable to those of freight trains. Under normal operating conditions, drivers braking from full speed usually cannot see the place where the train will stop.

Scheduling considers required path, i.e. whether a train from Warsaw to Gdańsk should run via Ciechanów and Malbork or via Łowicz and Bydgoszcz. However to ensure proper traffic control, it is necessary to take into account individual routes set for each train using track sections, overlaps, and side protections comprising tracks and switches, the availability of which is continuously supervised by track occupancy checking systems. For that purpose track circuits are still used on many lines and stations. They are using transmitters and receivers of electrical signals, and typically impedance bonds for separation between neighboring track circuits. Separation can also be based on use of differentiated frequencies. Lines and stations that have been upgraded in recent years employ axle-counters that detect electromagnetic field disturbances between transmitter and receiver heads, which is caused by the passage of a wheel in the counter zone. The counting heads are interlinked with comparators which, in the case of stations, are interlinked with interlockings, and in case of sections between stations with line block systems. Presently constructed interlockings are usually electronic ones ensuring setting and releasing of the routes on the main stations and remotely controlled smaller subordinated stations, as well as trains spacing on the sections between stations. The relevant information is communicated to the drivers using colour light signals. Relay interlockings however are still utilised and even being constructed. Older electro-mechanical interlockings as well as centralised mechanical interlockings (with signal wires and point wires) as well as mechanical key interlockings are still in use. Mechanical solutions are frequently equipped with colour light signals, but nearly two hundred mechanical semaphores are still in use on the Polish railway network.

Signalling equipment also include level crossing protection systems adapted to the category of crossing: automatic level crossing protection systems as well as manual level crossing protection systems operated by railway employees – locally by crossing keepers or remotely by traffic controllers. Level crossings belong to the places where railway CCTV is used to detect objects, such as cars that have not left the crossing zone.

Signalling equipment comprises also some specific categories of equipment like marshalling control systems, which control runs of individual uncoupled wagons over hump yards and support shunting management in relation to formation of the individual trains intended to serve individual destinations and grouping of wagons to be hauled to another shunting area on the basis of information provided by traditional methods and/or using telematics.

Signalling equipment comprises also derailers interlocked with interlockings and autonomous ones both protecting main tracks at the branch posts, especially where there is no reversing dead-end track providing safety. Signalling equipment also includes wagon tipplers and heating tunnels in seaports, as well as turntables and traversers used in the rolling stock stabling, service and maintenance areas.

Approvals (i.e. the formal processes of obtaining permission to use certain solutions in railway transport for specific purposes under precisely defined conditions) apply to both individual devices: e.g. track circuits, axle-counters, colour light signals, point machines, as well as to entire systems: e.g. interlockings, line block systems, level crossing protection systems. Not only functionalities are verified, but also safety cases covering quality management, safety management, technical safety, and relationship with safety cases of the generic products and with the safety cases of the generic applications.

2.3. Communication systems – from wired communication between traffic posts to wireless communication between traffic controllers and drivers and train crews as well as data transmission

Under normal operating conditions, with trains running as sheduled and signalling equipment fully operational, colour light signals enable drivers to drive the trains without disruptions. However, high quality operational communication has to be available as more than five thousand trains are running daily and half of them as freight trains are using paths ordered by freight railway undertakings during last two preceding days (as undertakings pay for ordered paths even if they do not use them), and each train is passing dozens and sometimes hundreds of colour light signals (as average distance between signals is less than 1 500 metres).

Voice communication between traffic controllers, dispatchers, and crossing-keepers as well as between traffic controllers and station staff shall also be provided. Wired communication systems are primarily used for this purpose, although wireless communication systems like radio-lines are also employed where necessary. Voice communication between traffic controllers and train drivers, shunting gangs, and staff present at the railway area e.g. responsible for inspecting and maintaining tracks, switches and other equipment along the railway lines shall also be provided. Such communication means, due to their nature, are wireless.

Analogue wireless simplex broadcasting systems which are used extensively on the railway network poses a major challenge as they are causing increasing risk of unauthorised use of train movement information. Digital systems providing point-point and point-multipoint connections and call prioritisation are employed as well. Wireless systems provide emergency call functionality, which significantly differs from solutions incorporated in analogue systems that automatically cause train braking. Digital systems trigger an alarm in the driver's cab and require driver action taking into account train's location – either braking immediately or stopping the train at a location convenient for evacuation and/or rescue services. All information exchanged is recorded.

Both legacy technologies and Voice over Internet Protocol (VoIP) communications are used. The dispatching terminals are configured for specific traffic control posts and provide connections to neighbouring stations, emergency services and trains in the area of responsibility of the respective traffic controller.

Digital communication systems are centralised – they are supervised and managed on a network scale. This enables user management, e.g. de-registering devices that have been stolen, but also creates risks for instance such as communication system unavailability in case of a blackout at central facilities. Thus, appropriate strategies are used in the design, operation and maintenance of communications facilities to ensure that communication remains functional despite backbone network failures, e.g. damage to fibre networks during construction works or central system failures, e.g. due to blackouts or hardware breakdowns.

Many IT based supporting systems rely on long-distance data transmission, using partly the railways' own fibre-optic connections and partly leased connections. Some IT based supporting systems which are utilised for railway transport also use internet data transmission.

2.4. Control command systems – from the creation and transmission of the electronic Movement Authorities to the on-going supervision of the compliance of running of the individual trains with applicable restrictions

An increase in train speeds lengthens braking distances and reduces the time for drivers to observe colour light signals. As a result driving trains on the basis of the trackside signals and indicators is becoming unacceptable from the point of view of traffic safety due to significant increase of the risk of human errors. By law, it is permissible to drive trains on the basis of trackside signals up to 160 km/h. Any train travelling at higher speeds shall receive all necessary information through cab signalling.

In Europe in the 20th century, Train Control Systems were implemented independently in individual countries. However, in the 1990s, it was deemed necessary to replace the different systems with a single European one. This system comprises digital components installed on railway lines, at the stations and in traction vehicles. On the infrastructure side, there are balises, encoders and RBC radio block centres, generating electronic movement authorities transmitted via wireless radio links. In contrast, the traction rolling stock relies on BTM balise transmission modules to receive data from balises, RTM radio transmission modules to receive data from radio, odometers for location supervision, EVC European vital computers being the main on-board computers processing Movement Authorities, as well as the driver's DMI driver machine interfaces displaying details regarding available route in a fully unified way, and a JRU juridical recording units and interfaces to on-board systems, in particular the SB service braking system and the EB emergency braking system.

Both standalone devices and individual systems are subject to approval. Not only functionalities are verified, but also safety cases covering quality management, safety management, technical safety, and relationship with safety cases of the generic products and with safety cases of the generic applications.

Implementation of the Train Control Systems requires operating regulations to be adapted accordingly and creates also necessity to change drivers' habits. This involves many challenges which require coordination between trackside equipment installed on railway lines and on-board equipment installed in traction vehicles. Moreover, coordination is required between implementation of the digital wireless communications system and implemetation of the European Train Control System. Finally, it necessitates the coordination of system baselines and configurations (the so-called ESC and RSC) and equipment levels (l1, l2, l1LS, STM).

2.5. Rolling Stock – from the contact between the wheel and the rail to the contact between the pantograph and the overhead contact line

No transport system can function without means of transport. The infrastructure shall be complemented by rolling stock that is fit for purpose. Electric and diesel multiple units are used as trains, from suburban ones to high-speed ones. Passenger and freight locomotives are used as traction vehicles adapted to the characteristics of the trainsets they are hauling. Shunting locomotives are used as well. Trainsets hauled by traction vehicles are composed with passenger coaches or freight wagons. Passenger coaches are constructed for defined types of traffic – e.g. for long-distance services with lots of seats, space for large luggage and toilets; in contrast, for urban services with lots of place for standing and many doors for access and egress. In that case lack of toilets is acceptable, but changes in floor height are generally avoided, etc. The means of transport are supplemented by inspection and maintenance vehicles, e.g. track geometry measuring self-propelled vehicles. There are also dual-mode road-rail vehicles capable of driving on tracks but also construction sites and other off rail areas; this includes excavators, loaders and aerial work platforms. Specialised maintenance trains are designed for the installation and repair of overhead lines. Rail grinders and rail milling machines, whether in the form of dedicated complete trainsets or individual vehicles that can be delivered by road transport and re-railed locally, are designed for track and turnout grinding. Track machines for tamping, profiling and ballast regulation-scraping, as well as vehicles dedicated for substructure compaction and stabilisation, ballast cleaners, track substructure cleaning machines, special wagons for transportation and laying of the switches delivered in blocks, rail welding machines as well as machines for continuous track laying, make it possible to quickly and precisely construct, modify, repair and maintain railway tracks. This list is by no means exhaustive.

Every railway vehicle needs appropriate running gear. Railway wheels` flanges guide rolling stock along the tracks while running. When it comes to wheels, strict material and strength requirements apply. Dimensions, geometry and permissible wear are defined in detail. Special undertrack wheel lathes in rolling stock maintenance halls are utilised to repair wheels by lathe machining. If no such lathe is available, each individual wheelset (axle plus two wheels) have to be dismantled before machining. Poor design and/or inadequate maintenance of the rolling stock can easily lead to derailments. Of course, derailments can and do occur due to other reasons too.

Usually vehicle bodies are placed on railway bogies, which typically have two axles. However three-axle bogies are also employed for wagons dedicated for particularly heavy loads such as iron ore. Multi-axle running gears are also employed in case of traction vehicles. In their case, however, the bogie systems are designed for a specific vehicle type and may include additional components such as inter-bogie couplings. There are two types of bogies: motor ones and carrying ones. They can necessitate, for example, changes in floor height. There is a primary suspension between the wheelsets and the bogie, and there is also additional secondary suspension between the bogie and the body of a vehicle itself. Both classical and leaf springs are used, as well as air and hydraulic suspensions.

Any traction vehicle needs propulsion. In this regard, electric motors and internal combustion engines are used. For environmental reasons, manufacturers are trying to replace the latter with new solutions such as hydrogen fuel cells. An electric traction vehicle, powered by overhead contact line, can be adapted to one or more electrical traction power supply systems becoming a multi-traction vehicle in the latter case. Vehicles adapted to DC power are fitted with inverters, as AC motors are smaller and offering better performance. Some traction vehicles are fitted with battery banks or an emergency combustion engine, creating hybrid-traction rolling stock. Attempts are being made to return to the railway electric linear motor concept. Vehicles with internal combustion engines are additionally equipped with generators which produce electricity utilising the work of the combustion engines, as electrical power supply is required for many on-board auxiliary devices, such as communication systems.

Electric vehicles are equipped with pantographs or current collection systems taking electric power supply from the third rail. Pantographs having their own suspension, have to work in a way ensuring keeping contact force between pantograph strip and overhead contact line within a narrowly defined range. Pantographs are also equipped with automatic dropper devices lowering malfunctioning pantographs. Sophisticated solutions are utilised as pantographs have to interact properly with the overhead contact lines disregarding staggering of the overhead contact wires, all types of vehicle suspensions, crosswinds and changes in overhead line tension.

Each railway vehicle have to be equipped with a railway brake – a pneumatic system utilising compressed air to hold friction elements away from the wheels or brake discs. Leaks and other failures cause the pressure in the main brake pipe to drop and automatically brake the train. Electrodynamic braking is used as well. Some vehicles are equipped with parking brakes, magnetic brakes and eddy current brakes. The pneumatic system employs electrical and electronic solutions to improve the braking system's performance while retaining the full functionality of the railway brake in the event of a power failure. To improve braking conditions, special sand dispensing nozzles are used on command from the driver's cab.

Trains are made up of railway vehicles. Vehicles therefore need to be equipped with draw and buffer gear – buffers and screw coupling or a Scharfenberg coupling, which transmits both compressive and tensile forces. Presently work is underway to implement a Digital Automatic Coupler. Due to the need to ensure train visibility and audibility, traction vehicles are equipped with lights and audible signals, which are subject to extensive requirements set out in normative documents. Lights or reflective signs are also used at the rear end of the train.

For some time, freight wagons carrying dangerous goods are being more and more equipped with derailment detection and/or prevention systems. Such devices detect the loss of a contact between wheels and rails, even if only one wheel is affected, and warn drivers accordingly or automatically reduce the speed.

Each vehicle has a superstructure, even a flat wagon. The type of the superstructure determines the intended use of a vehicle. Passenger vehicle superstructures employ highest number of vital elements, including doors and movable steps systems, emergency driver notification systems, emergency door opening systems, passenger-operated emergency braking systems, lighting – including emergency lighting in some cases, heating, ventilation, air conditioning, public address system, passenger area CCTV, passenger information systems, smoke and fire detection systems, automatic fire extinguishing systems, electrical sockets with power supply for passengers, occasionally vending machines with beverages/sweets/newspapers, as well as passenger Wi-Fi systems.

Each vehicle has a certain gauge – its maximum permissible outline that shall comply with the structure gauge. Gauges are defined as static, dynamic or kinematic depending on the scale how precisely running dynamics and impact of the suspension systems are taken into account.

2.6. Traction power supply – from the electric country grid to the contact between the overhead contact line and the pantograph

Many traction vehicles are electric, powered from the overhead contact lines above the railway track. Single-wire contact lines, catenaries and rigid overhead rails are used to that end. Catenaries are the most popular contact lines, providing a stable interaction between the pantograph and contact wire using messenger wires and droppers. Catenaries are subdivided into flexible and non-flexible ones as well as into fully compensated, semi-compensated and uncompensated ones. Various types of contact and messenger wire tensioning systems are used to compensate changes in the wires lengths caused by weather conditions. Normative documents specify the contact wire material, the strength parameters of the contact line, the geometry including height changes and staggering, and conditions for pantograph/overhead contact wire interaction, etc.

To guarantee proper power supply conditions, it is necessary to ensure correct electrical parameters at the pantograph/overhead contact wire interface, and this requires the overhead contact line power supply systems to be designed in accordance with the traction characteristics of the trains to be operated and in accordance with foreseen timetables so that the power supply substations provide appropriate electrical parameters over entire length of the supply sections.

Power supply stability and predictability, taking into account the potential breakdowns of the onboard traction equipment that shall not affect entire sections powered by a substation, as well as the failures of the overhead contact line and its power supply, requires appropriate electrical protection coordination arrangements. Electric shock protection as well as overhead contact line sectioning are also used, the latest using current-free sections in DC systems, and phase separation sections in AC systems and system separation sections.

Overhead contact line systems are complemented by power supply substations and sectioning cabinets. The latter significantly affect the current flow, ensuring electrical equilibrium in the sections between substations and, with the correct use of isolating switches, cut-off switches and circuit breakers, make it possible to minimise the areas affected by failures and allow better organisation of the overhead contact line maintenance and repair works. Power supply from both ends is usually used at the interface between substations and overhead contact lines. On the other side on the interface between substations and electric country grid redundancy is ensured by using dual connections to high- or medium-voltage lines (e.g. 60, 110, 220 kV) and in some cases by using two connecting supply lines to one or more high- or medium-voltage switchgears. Medium-voltage lines dedicated for railways are sometimes employed to ensure the high availability of overhead contact line power supply systems. Such lines are routed from commercial power supply switchgears to railway substations, but also along railway lines when sectioning cabinets are repleaced by substations due to increased power demand resulting from changes in speed and/or traffic load.

2.7. Components of infrastructure and rolling stock structures – from functional and strength characteristics to flammability

It is necessary to maintain the functional, endurance and quality characteristics of the railway lines and stations as these often serve many decades once in service, and of the rolling stock, built to serve thirty or more years without an overhaul. Thus, one important issue is to ensure the durability and quality of structural components. Some of these are tested according to railway normative documents.

For example, fatigue testing of sleepers, rails and fastening systems is carried out according to the requirements of railway normative documents, making the testing conditions and evaluation of the results dependent on the technologies used. Wooden, concrete and composite sleepers show different types of damage in fatigue tests. Recognised and formally established standards are used for wooden and concrete sleepers. For composite sleepers only first versions of the normative documents are available, and their use remains optional and experience with composite sleepers and their acceptance procedures are still being developed.

Construction products installed on railway lines and stations are also subject to testing. In this area, testing is defined by normative documents, but the characteristics of the products, where relevant standards are lacking, are determined by the manufacturers. For many products, so-called National Technical Assessments (NTAs) are created, to which manufacturers issue declarations, with one of the conditions for their credibility being that production is certified under so-called Factory Production Control (FPC) procedure.

Rolling stock components are also tested in detail. For example, fatigue tests representing the entire service life are carried out before acceptance for each type of a bogie frame. Similarly, brake blocks and discs are subjected to thorough type testing. Advanced strength testing also applies to couplings.

2.8. Materials – from fire properties of the rolling stock construction materials to the quality of the railway consumables

When building and outfitting rolling stock, particular attention shall be paid to the flammability properties of the materials used. These properties shall not only limit the occurrence and spread of fires but also ensure that the smoke emitted during a fire does not prove toxic to passengers or the driver. Fire tests are adapted to the place where the specific materials are used (floors, walls, seats) and the amount of material involved. This and many other materials and fire testing requirements are defined in a comprehensive seven-part railway standard. Consumable materials, for example, railway lubricants and agents used to remove unwanted vegetation from tracks, are also tested and independently assessed. Flammability testing also applies to equipment installed in the driver’s cab, such as the on board radio.

2.9. Infrastructure and rolling stock equipment and systems – from resistance to railway operating conditions to electromagnetic compatibility

Equipment and systems are also tested in many other respects. Among the most relevant, and regulated in detail by normative documents, are tests confirming resistance to railway operating conditions – high and low temperatures, frequent zero temperature crossings, humidity, snow, ice and other ambient conditions. Vibration and shock resistance are also verified in relation to the equipment locations and installation methods. Electromagnetic compatibility verification also plays a crucial role. For many frequency ranges, both electromagnetic immunity verification and verification of the maximum levels of electromagnetic interference generated are carried out, taking harmonic currents into account.

Moreover, functional verification is carried out under normal and degraded operating conditions. Depending on the intended use of the equipment and systems, functional safety and complete safety cases and, more recently, immunity to cyberthreats, are also subject to verification.

2.10. Operational procedures and traffic supervision – from normal operation conditions to rescue activities in case of emergency

Drivers drive the trains, but traffic controllers set routes for them. Each train has a timetable, which is adopted and made available to all relevant parties before the train starts to run. Only shunting runs with suitably low speeds are carried out outside the timetable. Passenger train timetables are long-term ones while freight train timetables are ordered ad hoc through IT systems. Railway undertakings using the online path ordering system use pre-defined catalogue of paths. Apart from timetables known to passengers, there are also service timetables for specific trains and days, which are handed over to the drivers and used during the run, and graphic timetables used by dispatchers in area control rooms that supervise the execution of the schedule by multiple trains and are responsible for resolving traffic conflicts and maintaining connections between different trains.

Information exchange and recording are also carried out during operation. For example, the Operating Performance Registration System collects source data for settlements between railway undertakings and the railway infrastructure manager. Moreover normative documents define messages and the form of their transmission supporting telematic applications for freight as well as passenger services. These include respectively, for example, electronic notification of readiness for entering the rail network, electronic transfer of responsibility for wagon groups between different freight railway undertakings, electronic information to railway undertakings and shippers about traffic disruptions affecting timetable and expected arrival times at destinations, as well as dynamic passenger information, including connections with other modes of transport.

Operational rules are also defined in detail, determining any possible situations and actions required to be taken, particularly by traffic controllers and train drivers. Notably, technical changes, such as the introduction of new electronic Movement Authorisations, shall be accompanied by changes or supplements to the operational rules. In addition to the operational and signalling rules, long-term local rules and short-term track closure rules are also created and used for such activities like tests carried out on the railway network.

2.11. Maintenance procedures – from diagnostic systems to the organisation of the maintenance works

Technical equipment and systems are subject to damage and breakdown, regardless of the technology used. The long service life of railway infrastructure and rolling stock requires equipment and systems to be maintained in an appropriate technical state. Maintenance staff needs to be provided with appropriate knowledge, tools, spare parts, means of transport and means of communication. Corrective and preventive maintenance are employed, whereby preventive maintenance can be either service-life-based or dependent on the condition of the equipment and systems. Thus, diagnostic systems play a critical role.

Up-to-date and complete documentation is invaluable in the context of maintenance. Installation and operating instructions, System Maintenance Documentation (SMDs), Operation and Maintenance Manuals (OMMs), maintenance staff training, having key spare components, as well as long-term maintenance contracts with system and equipment manufacturers are all part of a maintenance system meant to guarantee high availability of railways for the passengers, for the national economy and even for national defence.

2.12. Change management procedures – from technical, operational and organisational changes to the assessment of the Safety Cases and Risk Assessment and Evaluation Reports

The approaching two hundred years aniversary of the railway (with an 1829 steam locomotive being considered as the first-ever locomotive) leaves no doubt that the railway system is implementing ever newer technologies. At the same time, one shall note that railways are not and shall not be at the forefront of change. They are introducing solutions for which a certain amount of know-how has already been gained, allowing technical requirements, safety features, redundancies, maintenance procedures, etc. to be properly defined.

Railway transport, therefore, requires a formalised approach for change management regarding technical, operational and organisational changes. The significance of change is assessed in relation to the potential consequences of its failure, ability to monitor implemented change and change reversibility, as well as the scale of innovation and complexity, and the cumulative and reciprocal impact of the changes. Hazards are defined for changes: risks are defined for hazards and acceptance criteria are defined with respect to risks, based on normative documents, reference systems and/or explicit risk analyses. The risk assessment and evaluation reports are subject to evaluation by independent safety assessment bodies regarding the completeness of the risk identification and the adequacy of the safety measures applied.

Safety Assessment Bodies assess also much more formalised safety cases, which are required for control command and signalling systems since the late 1990s. Their introduction was linked to the approval of the programmable digital solutions for railway traffic control – electronic interlockings. The required safety integrity levels for both random failures and so-called systematic failures take into account such things as the technical characteristics of the components, the type of fail-safety, common cause failures, quality management, safety management, technical safety including operating conditions of the equipment and systems, interfaces, etc., reducing the risk in situations where simulating all possible failures and malfunctions becomes impracticable.

3. Normative and legal documents defining technical and/or procedural requirements for railway transport

Since the early days of railways, due to the technical characteristics of this mode of transport, railway companies have adopted documents regulating railway operation in detail, with national railways soon following in their footsteps. The strict application of the detailed and clearly formulated instructions by the staff of the various departments (permanent way maintenance department, signalling equipment maintenance department, traffic operation department, etc.) has ensured maintaining the necessary relationships and interdependencies between the different solutions, such as those between the rail running surface and the rolling surface and flange of the railway wheel, as already mentioned. In Europe, however, national railways have not been in operation for years. There are many passenger railway undertakings and even more freight railway undertakings and infrastructure managers providing paths for trains which, especially when it comes to freight, cross the borders between countries – the borders between the former national railways – on a massive scale.

3.1. Instructions of the infrastructure managers and railway undertakings

Both railway undertakings and infrastructure managers have their own instructions governing, in particular, dozens of areas in the core business of the railway entities – from detailed procedures for staff activities under normal and degraded operating conditions to maintenance rules specific for groups and types of technical solutions and from ensuring safety during work on tracks and in rolling stock to rules regarding collecting, storing and analysing operation and maintenance data.

There was a time when the national authorities were formally obliged to examine and approve the instructions of the railway undertakings and infrastructure managers to ensure the coherence of the railway system. Yet, the significant number of such documents and the lack of experience in day-to-day operations on the side of the national authorities resulted in delegating this task to the infrastructure managers and railway undertakings themselves. More often than not, this means that the managers providing the paths oblige the railway undertakings to strictly follow the instructions in force on the network, whether through the provisions of network statements or contractual obligations. Of course, this does not supersede the railway undertakings' instructions or the local or track closure rules. The number of documents in force requires not only training of employees before they are allowed to work but also updating and improving their knowledge and skills. This is done through things like the so-called periodic up-trainings.

In a handful of countries, infrastructure managers and railway undertakings have established joint organisations responsible for developing, adopting and improving the rules applicable to all railway undertakings and analysing the effects of such rules. One example is the multi-volume UK *Rule Book* developed and refined by the *Rail Safety and Standards Board* (RSSB). Nonetheless, even this approach does not ensure the level of railway consistency necessary for the seamless crossing of national borders. After all, from the nineteenth century, and throughout almost the entire twentieth century, care was taken to ensure that individual national railways differed technically, creating barriers to their possible use for military operations by neighbouring states. For this reason, different track and clearance gauges, as well as different overhead contact line power supply systems, pantograph strips geometries and materials, and signalling systems, including signal aspects, and permissible interference and electromagnetic interference resistance requirements were applied. For many years, also supporting the national industry was an important argument behind keeping diversity of solutions. After all, railway procurement contracts are significant, making them a serious factor affecting the economy, including GDP and employment.

However, this local-interest approach to railway technology has become a burden for the European concept of a common product market and the increasing application of the four basic freedoms in Europe. It has been acknowledged that the following shall be provided for railways, too:

- the free movement of goods, in particular, the possibility of using the same solutions in different countries, including the lack of the need to approve technical solutions in each country separately;
- the free movement of services, in particular, the possibility of carrying out work, e.g. design work, in any country for construction, alteration and operation in any other country;
- the free movement of people, in particular, eliminating or at least minimising the barriers to the acceptance of professional competencies and qualifications obtained and verified in one country in other countries; and
- the free movement of capital, in particular, eliminating financial and tax barriers between countries;

for a common market covering the whole territory of the European Union, as well as that of other European Economic Area countries and Switzerland, which apply European Union railway transport regulations.

3.2. CEN, CENELEC, ETSI and PKN standards and UIC and OSJD fiches

The solution, anchored in European Union law for technical solutions covered by common market rules, is European standards. While standards had already existed before, they were largely national in nature. The Polish Committee for Standardisation will be celebrating its one hundred years in 2024. However, the work of standards committees over the last 20+ years and the adopted documents have been international in nature.

European standardisation organisations like CEN, responsible in particular for standards in the fields of mechanics, materials and testing; CENELEC, responsible in particular for standards in electrical engineering and electronics; and ETSI, responsible in particular for telecommunication standards, receive mandates from the European Commission to develop and agree standards, which are then indicated in the EU Official Journal as harmonised standards for the common market. Standards for railways are adopted by CEN TC 256, CENELEC TC 9X and ETSI RP.

A prerequisite for entry into the European Union is full membership of CEN, CENELEC and ETSI and the implementation of EN standards into the national standards by translation or recognition. For example, Poland became a full member of CEN, CENELEC and ETSI on the 1st January 2004 in order to become a member of the European Communities, later transformed into the European Union, on the 1st May 2004.

Of course, rail transports began crossing state borders much earlier. Mention should be made of at least three international/intergovernmental organisations regulating technical, operational, formal and legal issues in relation to railway transport:

1. The International Union of Railways, UIC, a worldwide organisation operating since 1922 with the cooperation of national railways, has created hundreds of UIC fiches. At present, these fiches are not considered binding in Europe. At the same time, the European standardisation organisations – CEN, CENELEC and ETSI – have been given the full right to use the fiches for elaborating standards. This does not mean stopping the exchange of experience and the production of UIC technical documents, but changing their nature. Good practice reviews are currently being developed (UIC IRS – *International Railway Solutions*). The UIC also provides a platform for research and development cooperation for many new technologies.
2. The Organisation for Cooperation of Railways, OSJD, a technical, railway remnant of the Warsaw Pact, primarily covers 1520 mm gauge railways, including Russia, but also China, where the basic gauge is 1435 mm as in most European countries. OSJD has adopted, maintains and continues to create OSJD fiches. Adherence to these is important for crossing borders in Eastern Europe and Asia. There are also joint UIC/OSJD fiches for consignment notes, for example. The OSJD is both an international and intergovernmental organisation which means that, unlike the UIC, which does not bind governments, it can and does impose for its selected regulations the status of applicable law.
3. The Convention concerning International Carriage by Rail, COTIF, is an intergovernmental organisation covering not only all the countries of the European Union but also those of Eastern Europe, Asia Minor and North Africa. It regulates international railway traffic through many extensive

appendices to the Convention. One example is the RID regulations – a classification of dangerous goods transported by railway with detailed requirements for their securing and labelling.

The European Commission is a member of COTIF and works closely with UIC. While discussions about cooperation with the OSJD have been ongoing for years, certain competencies of the OSJD have been taken over by the CIS Railway Transport Council by a decision of the Russian authorities.

3.3. Technical Specifications for Interoperability (TSIs)

In case of many types of products, common market is based on a link between the law adopted by the European Parliament and harmonised standards, e.g. for toys on a Toys Directive and related CEN and CENELEC standards. This approach was not considered possible due to the complexity of railway transport. It was also recognised that a common market for railway transport, construed as the full application of the four fundamental freedoms of the European Union for the construction, maintenance and operation of railways, required the development, adoption and subsequent refinement of the Technical Specifications for Interoperability (TSIs). This concept was first introduced for high-speed railways and then, in 2004, for conventional railways.

Eleven TSIs are in force, each 100+ pages long; they were adopted by the European Commission by separate regulations and regulations amending the existing ones. They define the requirements for the five structural and three operational subsystems that make up the railway system in the European Union. The structural subsystems, i.e. infrastructure, energy, and control command and signalling – trackside instalations (INF, ENE, CCT) jointly constitute railway lines managed by infrastructure managers. The structural subsystems, i.e. rolling stock and control command and signalling – on-board instalations (RST, CCO) jointly constitute railway vehicles.

The TSIs define many of the detailed requirements; however, they refer to the provisions of CEN, CENELEC and ETSI standards in many respects, effectively making them mandatory. Few standards are referred to in this way in full. Most of the provisions in the standards provide the basis for meeting the essential requirements indicated in the Annex to the Railway Interoperability Directive. One hundred and ninety-seven European standards have now been harmonised with the TSIs. TSIs are also supplemented by specifications adopted by the European Union Agency for Railways and by NBRail recommendations jointly adopted by Notified Bodies (NoBo), i.e. bodies formally authorised to confirm the conformity of technical solutions with EU requirements.

National requirements also continue to apply in certain narrow areas. It is also necessary to verify the compatibility of new interoperable rolling stock with existing non-interoperable railway lines. All this is the responsibility of Designated Bodies (DeBo) authorised by the competent authorities of the individual countries.

3.4. Railway related essential requirements and basic requirements regarding construction works

Both the NoBos and DeBos examine technical solutions for compliance with specific EU or national requirements, respectively, and confirm their compliance with the essential requirements. This ensures that, on one side, technical progress does not have to be accompanied by constant legislative updates, and on the other, that the assessment bodies (NoBo, DeBo) are required to continuously maintain technical competencies and keep up to date with changes in legal and normative documents. The NoBo bodies have to make decisions based on the TSIs, the normative provisions referred to by them, the applicable European specifications adopted by the EU Railway Agency and the recommendations of NBRail. All individual detailed requirements are linked to the essential requirements. Moreover, DeBos shall make decisions based on the regulations, standards and normative documents set out in national law, which are linked to the essential requirements. Should a country want to impose requirements that are not linked to the essential requirements, this would be regarded as an unauthorised attempt to protect the internal market under the common market rules, triggering the corresponding formal legal action at the EU level.

Only six essential requirements have been defined for railways: safety, reliability/availability, health, environmental protection, technical compatibility and accessibility.

The essential requirements are briefly described in a Directive adopted by the European Parliament. They do not raise doubts as long as there is no need to confirm their fulfilment. While no one doubts that railways shall be safe, signing off that they indeed are, in light of the very first of the eleven paragraphs defining this essential requirement, is challenging. This paragraph states that (...) *The design, construction or assembly, maintenance and monitoring of safety-critical components, and more particularly of the components involved in train movements must be such as to guarantee safety at the level corresponding to the aims laid down for the network, including those for specific degraded situations* (...) and can only be confirmed based on the related specific requirements. This applies to all essential requirements. Therefore, they are linked to the detailed requirements in the TSIs. These, however, are not detailed enough in many cases. NoBos then decide whether or not the essential requirement is met based on harmonised standards. Independently of the Railway Interoperability Directive, the Construction Law and the related European Parliament Regulation on Construction Products apply to all structures, including railways. When finalising railway infrastructure projects, both permits for use under the Construction Law and permits for putting into service under the Railway Law have to be obtained. Under construction law, there exist the so-called basic requirements, which apply to railway infrastructure. Only seven basic requirements have been defined: load-bearing capacity and stability; fire safety; hygiene, health and environment; safety of use and accessibility of facilities; noise protection; energy conservation and thermal insulation; and sustainable use of natural resources.

The basic requirements apply to both structures and construction products, so they are taken into account, for example, when creating National Technical Assessments (NTAs) or carrying out Factory Production Control (FPC).

3.5. Common Safety Methods, CSMs

The Railway Interoperability Directive, like the Construction Law, is generally concerned with new, upgraded and, in some cases, renewals of the solutions. At the same time, railways operate many legacy lines and vehicles, which are still approved for service, and the complete system shall be safe. This is why the current Railway Safety Directive is in force alongside the Railway Interoperability Directive.

Under the former, the so-called Common Safety Methods, CSM, were adopted. The six CSM methods adopted by the Implementing Regulations of the European Commission and the Directive itself define the division of responsibilities and safety actions for railway infrastructure managers, railway undertakings, entities in charge of maintenance of rolling stock (such an entity is indicated in the rolling stock register for each railway vehicle), as well as national authorities in charge of safety supervision (NSAs) and those managing railway accident and incident investigations (NIBs).

The most widely used CSM method is the Common Safety Method for Risk Evaluation and Assessment, CSM RA, the basic principles of which are presented in Chapter 2.12. In this respect, assessment is handled by the so-called Assessment Bodies (AsBo). Contrary to their name, they do not assess risks but verify the correctness and completeness of risk assessments and issue safety assessment reports.

3.6. Procedural requirements regarding ensuring railway safety and availability

Relying on the common CSM RA safety method is considered insufficient in certain cases. For programmable digital solutions, including in particular computerised railway control command and signalling systems, but also for rolling stock, specific rules are required to guarantee sufficiently high resistance to random and systematic failures. The relevant procedures are set out in the RAMS standards, defining requirements for Reliability, Availability, Maintainability and Safety.

The principles for creating and verifying safety cases mentioned in chapter 2.12 are described in five RAMS standards, each over 100 pages long, dedicated to general principles, application guidelines, railway control command and signalling systems safety cases, software development and securing data transmission for control systems. Defined twelve lifecycle phases of the technical systems have been assigned successive steps for technical and operational analyses and the creation and completion of documents to guarantee the appropriate level of safety integrity.

Requirements and actions for the people and teams involved, including designers, verifiers, validators, project managers and independent safety assessors, have also been defined. The latter role, for solutions governed by EU law, is performed by AsBo risk assessment bodies empowered to conduct assessments according to the requirements of the CSM RA.

3.7. Requirements regarding railway resilience to cyberthreats

Since 2016, railways have also been covered by European cybersecurity regulations. Currently, a few railway entities hold the status of a so-called key service provider. However, following the 2022 changes adopted by the European Parliament, starting from 2024, all railway entities employing at least 50 people or having an annual turnover, or annual balance sheet total, of more than ten million euros – and thus nearly all railway infrastructure managers and railway undertakings – will be obliged to analyse cyber threats, define and implement appropriate protection means, as well as report cyberattacks and cyber incidents, among other things.

Such actions shall be taken in relation to IT systems and also to digital OT systems, for example, in relation to railway control command and signalling systems, digital wired and wireless communication systems, modern rolling stock, power supply substations control systems, infrastructure diagnostics and rolling stock diagnostics.

At the same time, the European Parliament is finalising horizontal cybersecurity requirements for products with digital components, which will also apply to railways. Except that they will not apply explicitly to railway undertakings and infrastructure managers, but primarily to equipment and system manufacturers and contractors building and fitting out infrastructure and rolling stock.

4. Areas of the Railway Research Institute Activities

A brief overview of the complexity of the railway system and the applicable normative and legal documents gives a simplified picture of the environment in which the Railway Research Institute operates. Nearly two hundred of the Institute's high-level specialists employ advanced tools and test stands to carry out work in the following areas:

- railway tracks – substructure, track construction, switches and crossings, geometric layouts of tracks and railway lines, rails, sleepers, fastening systems, baseplates, pads, etc.;
- railway stations – track layouts, platforms and access to platforms, public address systems, passenger information, adaptations for persons with reduced mobility, etc.;
- auxiliary infrastructure – trains stabling facilities, sidetracks, crossover connections, shunting tracks and reversing dead-end tracks, buffer stops, etc.;
- traction power supply – overhead contact lines and their equipment, substations, sectioning cabinets, isolating switches, cut-off switches and fast circuit breakers, etc.;
- railway control command and signalling systems – interlockings, line block systems, remote control, shunting control, automatic level crossing protection systems, etc.;
- railway automation systems – point machines/drives, switch rails position controllers, locks and switch point locks, turntables, traversers, derailers, switch heating systems, etc.;
- railway communications systems – wired and wireless, analogue and digital communications, whether installed in vehicles or on lines and in centralised facilities, etc.;
- electric and diesel multiple units – running gears, draw and buffer gear systems, braking systems, used materials, installed devices, etc.;
- traction vehicles – structural strength, braking, derailment protection, dynamic behaviour, crumple zones, main switches, pantographs, etc.;
- passenger coaches and freight wagons – running gears, braking, materials, equipment, adaptations for persons with reduced mobility, etc.;
- special vehicles, railway construction machinery, dual-mode road-rail vehicles regarding working modes of operation, transport modes, re-railing, integration into trainsets, etc.; and
- structural components – wheels and axles, ballastless tracks, platforms, crossing surfaces, overhead contact line supporting structures, foundation piles, etc.;
- conformity assessments – EC European conformity assessment and EC verification, national type and type conformity assessments, voluntary certification, etc.;
- preparing National Technical Assessments for construction products to be installed on railway lines – ballast, buffers, drainage, etc.;
- conducting Factory Production Controls for construction products and quality management system audits on the production of systems and equipment, etc.;
- independent assessments – concerning risk analyses, safety cases, safety management, documentation, procedures, instructions and protection means against cyberthreats, etc.

In doing so, the Railway Research Institute's staff use many specialised tools and test stands, for example:

- Nearly eight kilometres long closed test track in Żmigród with sidetracks and facilities, which are used for testing rolling stock and infrastructure components.
- Testing efforts regarding European Train Control System, crash tests to verify the design of crumple zones in rolling stock, shunting around small radius reverse curves, electromagnetic interference tests, vibration and noise measurements, as well as verification of infrastructure and safety components for use in track surfaces and overhead contact lines.
- A full-size friction pair test bench accredited by the International Union of Railways, which is used to test the interaction of brake pads with wheels and friction discs up to a speed of 500 km/h, taking into account the longest, steepest gradient on a railway track in Europe – the descent from the St. Gothard Pass.
- A full set of test benches for flammability testing of rolling stock materials in accordance with the current European standards.
- Numerous strength and fatigue test benches, including large-scale test benches for testing bogie frames or sections of ballastless tracks.
- Numerous climate chambers, used for testing resistance to weather conditions.
- A reflectionless chamber for complete and uninterrupted testing of all types of light sources.
- An electron microscope, used for studying the macrostructure and microstructure of rails, wheels and axle cracks after railway accidents.

- Workstations, samples and equipment for defectoscopy testing of rails, rail joints, wheels and axles. Test stands, models and equipment for the calibration of railway measuring instruments.

In the framework of the Polish Committee for Standardisation PKN, the Railway Research Institute also runs railway Technical Committees: PKN/KT 138 for railway technologies, covering, among other things, the full range of activities of CEN TC256 and PKN/KT 61 for electrical traction equipment, which in turn covers, e.g., the full range of activities of CENELEC TC9X. The Railway Research Institute also runs the ISAC-Kolej Information Sharing and Analysis Centre for the railway transport subsector, which analyses and exchanges information on cyberthreats and develops cybersecurity guidelines for railway infrastructure managers and railway undertakings. The Institute also participates in the national Partnership For Cybersecurity Programme, where information is exchanged between different industries, taking into account critical infrastructure and cooperation with the National Computer Security Incident Response Tram – CSIRT NASK. The Railway Research Institute is an associate member of both the UIC and OSJD. As part of the UIC, it takes an active part in the work of the International Rail Research Board, IRRB. It is also involved in numerous research projects, financed both nationally and from EU funds.

The Railway Research Institute is an active publisher as well. By no means is this activity limited to Problemy Kolejnictwa (Railway Reports), of which the 200th issue is being published. Every year, the Institute publishes several monographs on various rail transport issues. The Institute's staff also participate in many conferences and publish articles in scientific and popular science journals. Monthly open seminars organised by the scientific secretary of the Railway Research Institute also serve to build, expand and update railway staff's knowledge.

The accumulated expertise has allowed the Railway Research Institute to develop Railway Technical Standards. The first ones, developed in 2001–2002, concerned raising the speed on the Central Trunk Railway Line. The subsequent ones, still referred to in many railway project tenders by PKP Polskie Linie Kolejowe, were developed in 2008–2009 and are dedicated to upgrading railway lines to speeds of up to 200 km/h. They comprise sixteen volumes:

VOLUME I – Railway track
VOLUME II – Railway Structure Gauge
VOLUME III – Railway Engineering Structures
VOLUME IV – Electrical Traction Equipment
VOLUME V – Nontraction Electric Power Equipment
VOLUME VI – Control, Command and Signalling
VOLUME VII – Telecommunications
VOLUME VIII – Rolling Stock Defects Detection
VOLUME IX – Electromagnetic Compatibility
VOLUME X – Level Crossings, Parallel Roads
VOLUME XI – Structures
VOLUME XII – Small Architecture, Identification Systems
VOLUME XIII – Buildings
VOLUME XIV – Crossings And Line Protection
VOLUME XV – Environmental Protection
VOLUME XVI – Rolling Stock Requirements

More recently, between 2021 and 2023, Technical Standards and detailed technical conditions for the railway infrastructure of the Solidarity Transport Hub (under investment process managed by the Polish CPK company) have been developed. These standards are referred to in the CPK tender documents. They are more extensive and dedicated to the construction of new infrastructure rather than the upgrading of existing infrastructure, and include thirty-two volumes:

Volume A – Introduction to CPK Railway Standards
Volume I.1 – Railway Track – Geometrical Layouts
Volume I.2 – Railway Track – Construction of Civil Structures
Volume I.3 – Railway Track – Drainage of the Tracks
Volume I.4 – Railway Track – Structure Gauge
Volume I.5 – Railway Track – Geotechnical Research and Design
Volume II.1 – 2 × 25 KV 50 HZ AC Overhead Catenary and Traction Power Supply
Volume II.2 – 3 KV DC Overhead Catenary and Traction Power Supply
Volume III.1 – Engineering Structures
Volume III.2 – Tunnels
Volume IV – Non-traction Power Engineering
Volume V.1 – Non-public Roads
Volume V.2 – Public Roads
Volume VI.1 – Control Command and Signalling – Basic Equipment
Volume VI.2 – Control Command and Signalling – European Train Control System (ETCS)
Volume VII.1 – Wired and Wireless Communication Systems and Data Transmission
Volume VII.2 – Teletechical Systems and Telematics
Volume VII.3 – Devices for the Detection of Rolling Stock Defects (DSAT)
Volume VIII.1 – Passenger Stops` and Stations` Buildings
Volume VIII.2 – Technical Buildings
Volume VIII.3 – Structures
Volume VIII.4 – Small Architecture
Volume IX – Measures to Minimise Environmental Impact
Volume X – Conflicts with External Networks
Volume XI – Electromagnetic Compatibility (EMC)
Volume XII – Protecting Railway Lines

Volume XIII – Technical Support Facilities
Volume XIV – Health and Safety Support Systems for People and Properties
Volume XV – Survey Grid
Volume XVI – Rolling Stock
Volume XVII – Automatic Baggage Check-in Systems
Volume XVIII – Consistency Requirements for Safety, Security, and Cybersecurity

The technical standards applied by PKP PLK and those used by CPK are fully publicly available.

5. Summary

This brief overview of the Railway Research Institute's activities covers the key areas and types of works, offering a general, though not exhaustive, picture of staff's knowledge and skills, as well as research infrastructure, test stands and tools, which are employed.

At the same time, it should be noted that the Railway Research Institute takes great care to maintain the confidentiality of research results, technical and technological solutions and manufacturers' internal documents. The independence of experts evaluating proposed and applied solutions and quality management systems, as well as analysing various document types and verifying the completeness of risk identification and the adequacy of adopted safety measures, is also guaranteed.

The article makes it evident why the Railway Research Institute employs engineers and holders of PhDs in mechanics, electrical engineering, electronics, information technology, safety, durability, materials science, chemistry, metrology, etc. This is because it is vital to examine all aspects of technical and operational solutions, both internal and external, which may affect the railway under normal or degraded operating conditions, as well as during the construction, equipping or decommissioning of infrastructure and means of transport.